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Clerk.

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IN THE

Supreme Court of the United States.

THE STATE OF MISSOURI, Complainant

vs.

THE STATE OF ILLINOIS, and the SANITARY DISTRICT OF CHICAGO, Defendants.

ORIGINAL No. 4.

Motion to Open and Publish Testimony, and Print Pleadings.

CHARLES W. BATES,
SAMUEL B. JEFFRIES,
of Counsel.

THE STATE OF MISSOURI BY
HERBERT S. HADLEY,
Its Attorney General.

McGILL & WALLACE, Law Printers, Washington, D. C.

IN THE

Supreme Court of the United States.

THE STATE OF MISSOURI, Complainant,

vs.

THE STATE OF ILLINOIS AND THE SANITARY DISTRICT OF CHICAGO, Defendants.

ORIGINAL No. 4.

To the Honorable the Chief Justice and the Associate Justices of the Supreme Court of the United States.

Comes now the complainant by its Attorney General Herbert S. Hadley, and showing to the Court that the Commissioner heretofore appointed by order of the Court to take and return the testimony in the above entitled cause has this day deposited with the Clerk of this Court the depositions taken by him as Commissioner and has deposited the exhibits referred to in said depositions, part with the Clerk of this Court and part with the Marshal, as more specifically appears from the report of said Commissioner, moves the Court for leave to file said depositions, open and publish them and to file said exhibits.

And the complainants showing further that by rule entered herein on the 14th day of December, 1903, it was ordered that the record herein should be printed by the complainant under the supervision of the Commissioner, and that when so printed this cause should be

heard on said record printed under the supervision of the Commissioner as aforesaid as the printed record in the cause, and that said Commissioner has this day deposited with the Clerk of the Court twenty-five copies of the testimony taken before him, printed pursuant to said order of December 14, 1903, and has also filed in manuscript an index thereof, the complainant moves the Court to enter an order to fix the compensation of the Commissioner for his services in supervising the printing of said record and an order for printing the usual number of copies of the pleadings and motions and said index upon complainant's advancing to Clerk of the Court his fees for printing and supervising the printing of said pleadings, motions and index, as by the rule of this Court is provided.

THE STATE OF MISSOURI,
By HERBERT S. HADLEY,
Its Attorney General.

CHARLES W. BATES,
SAMUEL B. JEFFRIES,
Of Counsel.

Defendants assent to the granting of the above motions.

STATE OF ILLINOIS,
By W. H. STEAD,
Its Attorney General.

THE SANITARY DISTRICT OF CHICAGO,
By [illegible] TODD,
Attorney.

H. S. HOWLIN,
[illegible] C. DRENNAN,
Of Counsel.

JAMES H. McKENNEY,
Clerk.

IN THE

Supreme Court of the United States.

OCTOBER TERM, 1905.

STATE OF MISSOURI, Complainant,

vs.

STATE OF ILLINOIS AND THE SANITARY DISTRICT OF CHICAGO, Defendants.

Original No. 4.

HERBERT S. HADLEY,
Attorney-General of Missouri,
N. T. GENTRY,
Assistant Attorney-General.
For Complainant.

CHAS. W. BATES,
City Counselor of St. Louis,
W. F. WOERNER,
Associate City Counselor of St. Louis, and
SAM B. JEFFRIES,
Of Counsel.

IN THE

Supreme Court of the United States.

OCTOBER TERM, 1905.

STATE OF MISSOURI, Complainant,

vs.

STATE OF ILLINOIS AND THE SANITARY DISTRICT OF CHICAGO, Defendants.

Original No. 4.

STATEMENT.

This is a proceeding in equity, instituted on the 17th day of January, 1900, by complainant, the State of Missouri, against defendants, the State of Illinois and the Sanitary District of Chicago.

The Sanitary District of Chicago is a "public corporation," organized under the laws of the State of Illinois and located in part in the city of Chicago, and in the county of Cook, in the State of Illinois, and is a citizen of the State of Illinois.

The remedy asked for is an injunction against defendants, restraining them from receiving or permitting sewage to be received or discharged into the artificial channel or drain con-

structed by The Sanitary District of Chicago as hereinafter explained; under authority derived from the defendant state, in order to, and for the purpose of carrying off and discharging the sewerage of Chicago in the Mississippi River a short distance above the city of St. Louis.

Prior to the construction of this canal, the sewerage of Chicago has been discharged by way of the Chicago river, into Lake Michigan, while since the opening of the drainage canal by defendant, the Sanitary District of Chicago, the sewage of the city has been caused to flow therefrom through the canal into the Des Plains river and from thence into and down the Illinois river, passing into the Mississippi river at Grafton, a small town situated upon the Mississippi thirty-two miles above the intake of the St. Louis waterworks.

The bill of complaint alleges that the nature of the injury complained of is such that an adequate remedy can only be found in the Supreme Court of the United States, at the suit of the complainant.

The substantial purpose of the complaint is to subject the public work of the construction and operation of the drainage channel constructed from the Chicago river at Chicago, southwestwardly to, and connecting with, the Des Plains river at Lockport, a point immediately above the city of Joliet, to the court's supervision, upon the charge that the method of construction and operation or maintenance creates and constitutes a continuing nuisance, dangerous to the health of the people of the State of Missouri; that the operation of the canal on the part of defendants, if not restrained, results in the daily transportation, by artificial means, and through an unnatural channel, of large quantities of undefecated sewerage, and of accumulate deposits in the harbor of Chicago, and in the bed of the Illinois river, which poisons the water supply of the inhabitants of Missouri and injuriously affect that portion of the Mississippi river which lies within complainant's jurisdiction.

No attack is made upon the canal or artificial channel as an unlawful structure, nor is any attempt made to prevent its use as a waterway. Complainant seeks relief against the pouring of

undefecated and unpurified sewage and filth through it by the artificial arrangements into the Mississippi river to the detriment of complainant and its inhabitants.

The language of the bill is as follows:

"The complainant, the State of Missouri, and one of the states of the United States, brings this, its bill of complaint against the state of Illinois, one of the states of the United States, and the Sanitary District of Chicago, a public corporation, organized under the laws of the state of Illinois, and located in part in the city of Chicago, and in the county of Cook, in said state of Illinois, and a citizen of the state of Illinois.

"And your orator complains and says that it is a state containing a population of upwards of three millions of people, and lying on the west bank of the Mississippi river, a public, navigable and running stream, and having a frontage on said stream of over four hundred miles.

"And your orator shows that by the act of Congress providing for the organization and admission of Illinois and Missouri as states of the Union, it was declared that the western boundary of Illinois and the eastern boundary of Missouri should be the middle of the main channel of the Mississippi river, that the shores of the Mississippi river, where its waters form the Missouri and Illinois boundary, and the soil under the waters thereof, were not granted by the Constitution of the United States, but were reserved to the states of Illinois and Missouri, respectively.

"And your orator shows that the states of Missouri and Illinois each have concurrent jurisdiction over the waters of the Mississippi river forming the boundary between them, and each of said states has exclusive territorial jurisdiction over that portion adjacent to its own shore, and your orator shows that the Illinois river empties into the Mississippi river at a point above the city of St. Louis, on the Illinois side of said Mississippi river.

"And your orator further shows that within the territory of your orator and on the banks and shores of said Mississippi river and below the mouth of the Illinois river are many cities

and towns in the State of Missouri, and many thousands of persons who are compelled to and do rely upon the waters of said river, in their regular, natural and accustomed flow, for their daily necessary supply of water for drinking and all other domestic and agricultural and manufacturing purposes, and for watering stock and animals of all kinds, and that said Mississippi river has been flowing in its regular course and has been used for the purposes aforesaid by the inhabitants of the said State of Missouri for a time whereof the memory of man runneth not to the contrary, and that said river and its waters and the use thereof for drinking, agricultural and manufacturing purposes, in their accustomed and natural flow, are indispensable to the life and health and business of many thousands of the inhabitants of the State of Missouri and of great value to your orator as a state.

"And your orator shows that cities and towns below the mouth of said Illinois river, within the territory of your orator, do and are compelled by means of waterworks, water towers and intakes, built and constructed for that purpose, to supply the inhabitants of said cities and towns with an adequate supply of pure and wholesome water, fit and healthful for drinking and all other domestic purposes and uses, from the said Mississippi river so flowing in its ancient, accustomed and natural course.

"And your orator shows that said waterworks systems are constructed with reference to said Mississippi river and for the purpose of taking water therefrom and not from any other source.

"And your orator shows that heretofore, to wit, in 1889, the state of Illinois enacted a law, known as the Sanitary District Act, together with an act for the improvement of the Illinois and Des Plains rivers, and that under said act of said state the said corporation, known as the said Sanitary District of Chicago, was organized and is now existing and operating, and that by express terms of said act any canal or drain corporation organized in accordance with its provisions may have conditions, restrictions or additional requirements placed on said corporation, or the act authorizing the creation of said corporation may

be amended or repealed, and that by the express provisions of said act, before any water or sewage shall be admitted into any channel constructed under said act, the trustees of said channel shall notify the Governor of Illinois of the completion of said channel, and the Governor of Illinois shall appoint three commissioners to examine said canal or channel, and report to the governor if the same complies with the act of the state of Illinois; and if it does, the governor shall authorize the water and sewage to be turned into said channel; and that without the said permit it can not be so turned in; and that by the general provisions of said act said channel is at all times subject to the control and supervision of the state of Illinois and her authorities.

"And your orator further shows that the Chicago river is situated in the basin of Lake Michigan and has two forks or branches flowing through the city of Chicago and into Lake Michigan, and that the natural drainage of Chicago, Illinois, is into Lake Michigan, and the sewage and drainage of the territory embraced in the defendant's district, the Sanitary District of Chicago, is led into or flows into the Chicago river and Lake Michigan.

"And your orator further shows that the defendant herein, the Sanitary District of Chicago, with the authority of the state of Illinois, and acting as a governmental agency of said state, and under the supervision and control and subject to the approval of the state of Illinois, has constructed a channel or open drain from the west fork of the south branch of the Chicago river, in the city of Chicago and county of Cook, in the state of Illinois, to a point near Lockport, in the county of Will, in said state, where said channel or drain connects with and empties into the Des Plains river, which empties into the Illinois river, and which latter river flows and empties into the Mississippi river at a point distant about forty-three miles above the city of St. Louis, Missouri.

"And your orator further states that the channel built by the Sanitary District of Chicago was so built by said Sanitary District as one of the governmental agencies of the state of Illinois, and by the pretended lawful authority of said state, and

under the direction, supervision and control and governmental power of the state of Illinois, which said state has heretofore at all times sanctioned and now, through its governor and other officers, sanctions the building of said channel and opening thereof.

"And your orator further shows that in the construction of said channel or drain the defendant, the Sanitary District of Chicago, Illinois, cut through the natural ridge or watershed which divides the basin of Lake Michigan from the basins of the Des Plains and Illinois rivers and the basin of the Mississippi river, and that having so constructed said channel and having about completed the same, and having, under the sueprvision of and with the sanction of the state of Illinois, extended said artificial channel through said natural divide of the watershed, the defendants now propose and threaten to receive into said channel or drain the sewage matter and filth of the Sanitary District of Chicago, which embraces nearly the whole city of Chicago and a portion of the county of Cook, and, without any legal authority so to do, has already in part effectuated its said threat and purpose and threatens to permit and to cause said sewage and filth, by artificial means of pumping and otherwise, to flow through the channel or drain towards and into the said Des Plains river and eventually into the Mississippi river, thereby, with the approval of and subject to the inspection and control and supervision of the state of Illinois, and by the pretended authority thereof, reversing the natural flow of said Chicago river.

"And your orator further shows that the sewage matter and poisonous filth which it is thus threatened to receive and to permit and to cause to flow through said artificial channel into said Des Plains river is that which is created by a population of upwards of one and one-half millions of people, besides that which is created by a great number of stock yards, slaughter establishments, rendering establishments, distilleries and other business enterprises and industries lining both sides of the Chicago river, producing filth and noxious matters; all of which are there discharged into the said Chicago river or drained therein from the surface.

"And your orator further shows that for many years past the said city of Chicago, the greater portion of which is embraced in the limits of the defendant corporation, the Sanitary District of Chicago, as aforesaid, has been discharging its sewage matter and filth into the Chicago river and into Lake Michigan in such large quantities that much of it has accumulated in the bed and along the sides of the river and upon the bed of said Lake Michigan, near the shores thereof, and that the plan threatened and attempted now to be adopted by the defendant, the Sanitary District of Chicago, acting in conjunction with and subject to the control of the defendant, the state of Illinois, and by the pretended authority of the said state of Illinois, will loosen said accumulated matter and filth, and will also direct it and cause it to flow towards and into said artificial channel or drain, and thence into said Des Plains river, and finally into the Mississippi river and into the waters thereof within the jurisdiction and under the control of your orator and past the homes of the inhabitants of your orator and the towns and cities within the borders of your orator, and past the waterworks of said cities and towns within the State of Missouri.

"And your orator further shows that the amount of said undefecated filth and sewage and poisonous and unhealthful and noxious matters proposed to be, and now about to be, permitted to be turned into said artificial channel and through said Des Plains and Illinois rivers into the Mississippi river from the said Sanitary District of Chicago by the defendants, acting jointly, will amount daily to about fifteen hundred tons, and that if defendants should be permitted to carry their said threats into execution, and should cause said above amount of undefecated sewage and other poisonous and noxious matters, which would otherwise flow into Lake Michigan, to flow into the Mississippi river, that the waters of the Mississippi river within the jurisdiction of your orator will of a certainty be poisoned and polluted and rendered wholly unfit and unhealthful for drinking and domestic uses, and will render wholly valueless and entirely worthless the various waterworks systems of towns and cities on the borders of the State of Missouri, established and acquired at great cost and expense, and will deprive your orator, the State

of Missouri, and its inhabitants, of the right to use the waters of said river for drinking and all other domestic and manufacturing and agricultural purposes, as said water has been so used in its accustomed and natural flow heretofore for the length of time that the memory of man runneth not to the contrary thereof.

"And that said threatened action of the defendants will amount to a direct and continuing nuisance and be an interference with the use by your orator and its inhabitants of the waters of the Mississippi river flowing in their natural state, polluting and poisoning the same by the means aforesaid, whereby the health and lives of the inhabitants of your orator will be endangered and the business interests of said state will be greatly and irreparably injured, and which said damage to the lives and health and the business interests of said state resulting from said poisoning and polluting of said waters as aforesaid to your orator can not be estimated in money value.

"And your orator on information and belief states and charges the fact to be that said fifteen hundred tons of poisonous undefecated filth and sewage of said Sanitary District of Chicago will be daily carried through said artificial channel and sent through the Des Plains and Illinois rivers into the Mississippi, and great quantities thereof will be deposited in the bed and soil of said river belonging to your orator and wholly within the jurisdiction thereof, to your orator's great and irreparable damage, and that the fifteen hundred tons of undefecated sewage and filth now about to be daily injected into the waters of the Mississippi river and into the portion thereof over which the State of Missouri has jurisdiction, and from which thousands of her inhabitants obtain drinking water, will pollute and poison the said water of the Mississippi river to such an extent as to render it unwholesome and unfit and unhealthful for use for drinking by the said inhabitants in the territory of your orator and unfit for use for watering stock and for manufacturing purposes.

"And your orator further shows that great quantities of undefecated sewage turned into the Mississippi river in the manner and by the means aforesaid will poison and pollute

said water with the germs of disease of various and many kinds. And your orator further shows that the acts herein complained of on the part of the state of Illinois, acting in conjunction with one of her governmental agencies, the said Sanitary District of Chicago, will cause a continuing nuisance in the Mississippi river, and that the said state of Illinois has no power or authority to cause or permit or assist in causing the commission and continuance of a nuisance in the flowing waters of the Mississippi river, a navigable stream, to the detriment and irreparable and continuing damage and injury of the State of Missouri, and the continuing and irreparable injury to the lives and health of the citizens and inhabitants of the State of Missouri, and that unless restrained by the order and decree of this court the defendants, the state of Illinois and the Sanitary District of Chicago, acting together, will, in accordance with the terms of the act under which said Sanitary District is organized, under the permit and authority of the governor of Illinois and of the state of Illinois, turn said water and sewage aforesaid, by the manner and means aforesaid, into the Des Plains and Illinois rivers, and thence into the Mississippi river, all of which your orator says and avers is contrary to equity and good conscience and would result in the manifest and irreparable injury of your orator and the health of her citizens in the premises, and your orator is wholly without remedy at law and without any adequate remedy to prevent the flowing of said sewage as aforesaid, save by the interposition of this court.

"For as much as your orator can have no adequate relief except in this court, and to the end thereof, that the defendants may, if they can, show why your orator should not have the relief prayed, and to the end that the defendants may make a full, true, direct and perfect answer to the matters hereinbefore stated and charged, but not under oath, an answer under oath being hereby expressly waived, and to the end that the defendants, their officers, agents, servants and employes may be restrained by injunction issuing out of this court from receiving or permitting any sewage to be received or discharged into said artificial channel or drain, and from permitting the same to flow or causing

the same to be made to flow through said channel or drain towards and into the Des Plains river, your orator prays that your honors may grant a writ of injunction, under the seal of this honorable court, properly restraining and enjoining the defendants, the officers, agents, employes and servants of the Sanitary District of Chicago and the state of Illinois, from permitting or causing any of said sewage to be discharged into said channel or drain, and from permitting or causing said sewage and poisonous filth thence to flow into said Des Plains river; that defendant, the state of Illinois, be enjoined and restrained from issuing to its co-defendant permission and authority to do and perform the acts aforesaid or to allow them to be done; and your orator also prays for a provisional or temporary injunction pending this cause, restraining and enjoining the several acts aforesaid, and for such other and further relief as the equity of the case may require and to your honors may seem meet.

"May it please your honors to grant unto your orator not only a writ of injunction conformable to the prayer of this bill, but also a writ of subpoena of the United States of America, directed to the state of Illinois, the governor and attorney-general thereof, and to said Sanitary District of Chicago, its officers, trustees and agents, commanding them on a day certain to appear and answer unto this bill or complaint, and to abide such order and decree of the court in the premises as to the court shall seem proper and required by the principles of equity and good conscience."

On the day the bill was filed the dam at the controlling works, near Lockport, was lowered and the unpurified sewage and filth from Chicago started on its journey down the Des Plains, Illinois and Mississippi rivers. Since then it has been constantly and continuously operated by defendant Sanitary District of Chicago without hindrance or interruption.

Defendant filed a demurrer to the bill which was argued on November 12th and 13th, 1900. The court delivered its opinion thereon on the 28th of January, 1901.

Defendants were thereupon given time in which to answer. The answers were filed on the ..... day of ....., 1901.

Whereupon Frank S. Bright, Esq., of Washington, D. C., was appointed commissioner to take the testiomny and return the same into court.

The taking of testimony was commenced on the 17th day of February, 1903, and continued at intervals till May 28th, 1904, when it was completed.

During the time above mentioned witnesses were examined on the part of complainant at St. Louis, Mo., and Washington, D. C., while testimony on behalf of defendants was taken at Chicago, Peoria, Peru, LaSalle, Ottawa and Morris, Illinois, at Baltimore, Md., and Philadelphia, Pa.

A trip of two weeks was made up the Illinois river on a steamboat by the commissioner on which testimony was taken at Grafton, Hardin, Pearl, Gravel Point, Meridosia, Beardstown, Campsville, Pekin, Chiticochie, Henry and other points on the river.

For many years prior to 1895 the city of St. Louis derived its water for drinking, domestic and manufacturing purposes from the Mississippi river at a place known as Bissel's Point, about two and one-half miles north and above the "Eads bridge" which spans the river at the foot of Washington avenue; Washington avenue extending east and west in such way as to pass practically through the heart of the city dividing it into two approximately equal parts. To further identify and locate Bissel's Point so that it may be easily and readily understood, it will be known that the present "Merchants' bridge" crosses the river about two hundred yards below and south of the intake (now abandoned).

The intake extended from the bank of the river into the water about one hundred feet, except in exceedingly low stages of the river when the water receded entirely from it. In order to secure ample water during such times a flexible pipe was used which was carried out into the stream and water drawn through the pipe by means of a low pressure pump. Under such conditions the intake was abandoned.

Large reservoirs were constructed near the intake and the water being pumped into them was afterwards distributed throughout the city for use.

In 1892 a severe typhoid epidemic occurred in St. Louis, which raised the total typhoid deaths in the city from one hundred and sixty-six occurring in 1891, to four hundred and eighty-eight in 1892. This large increase in typhoid received the attention of the health authorities of the city and was thoroughly investigated by public officials having in charge the city's water supply, and by the local physicians. Harlem creek passes through a portion of the city and empties into the Mississippi now about one thousand feet above the intake at Bissel's Point. A number of cases of typhoid fever developed in the locality drained or sewered by Harlem creek. Soon after the existence of these cases, typhoid became most prevalent throughout the city. In the course of a few weeks it became epidemic. This condition, as above stated, brought about an investigation. It was found that the sewage from the creek above named flowed out into the river passing down and into the intake. This, on account of the difference in the water, was readily observable to the investigators. In fact, was plainly visible to any one standing on the bridge connecting the intake with the reservoirs. In order to relieve the situation a dam was constructed across Harlem creek at its mouth and a pump used to convey the water from the creek to a place below Bissel's Point where it was discharged into the river. This was done to prevent a contamination of the water supply. The effect of this change in conditions manifested itself at once the result being that within a short time deaths from typhoid had become reduced to the normal condition. Thus we have a very striking example of the effect produced upon the people of a city who drink and use their own sewage. In other words, the effect of a sewage polluted water upon those who use it for domestic purposes.

This discovery brought the people of St. Louis to a realization that the city had become so extended in populous territory that the intake at Bissel's Point was located in an undesirable place, a large part of the people residing north and above the intake and sewering either directly into the river or into Harlem creek and from thence into the river above Bissel's Point. In fact, the water supply once reasonably safe was on account of

the growth of the city, found to be seriously infected with disease producing organisms.

The city being driven to make a change in its water supply finally determined to abandon the intake at Bissel's Point and construct a new plant at Chain of Rocks. This was done, the new plant being put in operation in the latter part of 1894.

Chain of Rocks is located on the Mississippi river eight miles above Bissel's Point or about ten and one-half miles above Eads bridge. At this point a tunnel, constructed of masonry, is extended into the river about 1,500 feet from the shore. At the end of the tunnel in the current of the river is a tower connected with the tunnel. This tower is known as the "Intake Tower" of the St. Louis Waterworks. From the tower to the Missouri shore of the river is a "chain of rocks" so constructed as to deflect the water from the Missouri shore causing a swift flow to pass down around the tower. From this rock constructed dyke the place derives its name, "Chain of Rocks." The tower contains openings down through which the water passes into the tunnel. From the tunnel it runs into the uptake reservoir, from whence it is pumped into large reservoirs, six in number. The water is allowed to remain in those large reservoirs about 36 hours. It then passes out into a conduit and is carried south and west to Baden, a distance of about six miles, where, by the use of high service pumps, a portion of it is drawn into what is known as the high service tower located on Grand and Lafayette avenue. From this tower the western and central portions of the city are supplied with water. The remainder of the water passing through the conduit to Baden is diverted into the old reservoirs at Bissel's Point, and from these reservoirs, by the use of low service pumps the central and low parts of the city are supplied. The foregoing constitutes the St. Louis Waterworks system as it is today, and as it has been since the removal of the intake to Chain of Rocks from Bissel's Point in 1894. The only treatment afforded is to allow the water to stand in the reservoirs from 24 to 36 hours before distributing it to the people. Since the removal of the intake to the Chain of Rocks there has been no change in the manner or character of treatment.

The Missouri river enters the Mississippi about 8 miles above "Chain of Rocks," and the Illinois finally joins with the Mississippi about 24 miles from the mouth of the Missouri, or 32 miles above Chain of Rocks. With St. Louis, the metropolis city of the State, with a population of almost one million, situated upon the Mississippi river immediately below its confluence with the Illinois and Missouri rivers, and with the Mississippi as its only possible available source of water supply, it is essential to the State of Missouri to guard well the sanitary condition of this stream and protect it as far as possible from the damaging effect of sewage pollution and infection of cities, districts and communities situated upon neighboring watersheds.

Ascending the Missouri river, we find a large body of water draining an extensive area of territory of 520,000 square miles, comparatively thinly populated The urban population on this area or watershed being 1,090,832, according to the census of 1900, taking into consideration all towns and cities having 4,000 or more inhabitants. This river constitutes the natural drainage basin or channel of a very extensive portion of the central western part of the United States, consisting in parts of Missouri, Kansas, Iowa, Colorado, Nebraska, Montana, North and South Dakota and Wyoming. It also claims a large part of the British possessions as belonging to its drainage area.

The area of the Mississippi river watershed above the mouth of the Illinois river at Grafton is 286,535 square miles, having an urban population of 1,219,645. This drainage area covers a portion of the following states: Missouri, Illinois, Iowa, Minnesota, Wisconsin, North and South Dakota.

The area of the natural watershed of the Illinois river is 32,081 square miles, covering a portion of Illinois, Wisconsin and Indiana.

The urban population of the natural watershed of the Illinois river is 385,305. The urban population of both the Mississippi and Illinois watersheds being based upon the total number of inhabitants residing in towns and cities of 4,000 and over.

The total urban population of the Mississippi above St. Louis, including the Missouri and Illinois rivers, is 2,695,782, with a combined drainage area of 838,616 square miles.

The Missouri river has 496,919 more square miles of watershed and 705,527 more urban population than the Illinois.

The Mississippi river has 263,454 square miles more watershed and 834,340 more urban population than the Illinois, exclusive of the Sanitary District of Chicago.

The relation of square miles of watershed to population of the three rivers is as follows:

Missouri river, $2^{1}/_{10}$ population to 1 sq. mi.

Mississippi river, $4^{2}/_{10}$ population to 1 sq. mi.

Illinois river, $16^{7}/_{10}$ population to 1 sq. mi.

Mississippi, above St. Louis, including Missouri and the natural Illinois, $3^{2}/_{10}$ population to 1 sq. mi.

The Mississippi, above St. Louis, including the Mo., Ill. and the Sanitary District of Chicago, $5^{6}/_{10}$ population to 1 sq. mi.

The Ill., including the Sanitary District of Chicago, 103.3 population to 1 sq. mi.

Where the population of the Sanitary District of Chicago is used in the foregoing determinations, it is assumed to be, in full figures, 2,000,000 inhabitants, nearly all of whom reside in the city of Chicago.

By the addition of the population of the district to the watershed of the Illinois river, its population per square mile on the 17th day of January, 1900, was increased 520 per cent., or, differently expressed, is greater by 5.2 times the population residing upon its natural watershed. The opening of the canal at Chicago may also be said to have increased the population of the Illinois drainage basin from 385,305 to 2,385,305, or its original and natural population has become more than multiplied by six.

By the addition of the Sanitary District of Chicago to the Mississippi river watershed above St. Louis, including the Missouri and Illinois, the urban population sewering into the Mississippi has become increased by 75 per cent., or from 2,695,782 to 4,695,782, so that since the opening of the canal the water at St. Louis has in its flow received an increase of sewage polluting material to the extent of 75 per cent. over conditions existing prior to January 17, 1900.

The Missouri river from its source to the Mississippi travels

a distance of over 2,000 miles; the Mississippi from its source to St. Louis travels more than 900 miles; while the water from Chicago passes through the canal of the Sanitary District of Chicago into the Des Plains river, and thence into and down the Illinois and Mississippi to St. Louis, a distance of 355 miles.

The character of the soil and territory traversed and drained by the respective rivers from a geographical, historical and geological standpoint is well known. All are known as western rivers, acting as drainage basins for the purpose of carrying off the sewage waste and filth of the people residing upon their respective watersheds.

Chicago is a large and populous city of about 2,000,000, and is rapidly growing beyond that number. It is an important Manufacturing and trade center for the northern and northwestern territory of the United States. It contains many industrial enterprises and is one of the largest, in fact the most important live stock markets of the world; being noted for its extensive slaughterhouses and dressed beef and meat manufacturing establishments.

The Chicago river, and in fact all of the rivers that empty into the lake along the southern and western portions of Lake Michigan, you may say, have been formed as the water receded, so that they run parallel with the lake. They have been shut out from the lake as the waters receded, by ridges of sand and drift, which left them running parallel with the lake. There are no rivers reaching back into the country and discharging directly into the lake in the ordinary form of drainage. The rivers are all parallel, with occasional points where they break through the obstruction into the lake, and hence they are of minor importance, only covering a few square miles of drainage territory. The Chicago river proper is short, originally not over a mile long from the lake back to the confluence of the two forks, one leading from the south and one from the north; the southern fork, called the south branch, and the northern fork, called the north branch. The northern branch really drains the most territory and from a district of higher elevation as its source, in the state of Wisconsin. The south branch at a distance of about five miles from the lake, as it originally existed, has two

branches, one known as the west fork, and the other as the south fork. The south fork drains a very limited territory, and can hardly be called a stream, except in flood periods. The west fork drains a small territory also, except as the flood waters of the Des Plains river at a distance of about nine or ten miles from the lake would break over and pass down it towards the lake. During such times it became much of a stream.

The Chicago river enters the lake at a point directly opposite the heart of the city and with its branches and forks constitutes the natural outlet for the sewage, manufacturing and domestic waste of the city, except as to that portion sewering directly into the lake. For many years prior to January 17, 1900, it was not only a sluggish stream, but may be said to have been without a current to any preceptible extent. It was very foul, black in color and decidedly ill smelling. Oftentimes it was covered with a black slime and was subjected to considerable agitation due to the gases arising from the putrescent matter contained in the water.

Chicago lies very low. The elevation of the grounds within the city is from the lake level to a height of about twenty-five feet above the lake level, a very large portion of the city lying but a few feet above the lake level, so that its plan of sewage disposal has been to fill the streets and raise the grade above the original surface of the ground. In portions of the city, sewage districts have been laid out and the sewers so constructed below the lake level as to necessitate the pumping of the sewage at the sewer outlets. In other words, the sewage is pumped back to the lake level.

The original character of the soil on which Chicago is situated is reasonably firm, the greater portion being clay, originally overlaid with prairie soil. There is no gravel in the surface of the loamy soil; stone, however, is found underlying the clay. Some portions of the city, and the territory traversed by the drainage canal, cobblestone and a gravel material to a greater or less extent is found. In other places, a great mass of boulders cemented with clay exists.

The flat topographical condition of the land upon which

Chicago is situated rendered it impossible for the Chicago river to convey the sewage of the city a sufficient distance to remove its ill-effect upon the health and the convenience of the city. Frequent attempts have been made to open the Chicago river to a greater depth, extending its forks and branches, but all these endeavors have proven unsuccessful. No effort, however, has been made to treat the sewage in a systematic way so as to relieve it of its harmful substance before discharging it into Lake Michigan.

It will be observed that Lake Michigan is the natural basin for the sewage disposal of the city of Chicago. Yet, the facilities naturally provided for the city have become inadequate unless artificial means be resorted to. First, in either diverting the sewage to another watershed or by putting it through some course of treatment. At an early day the Illinois and Michigan Canal was constructed by the defendant state from the Calumet river, some distance south of the Chicago river, to the Des-Plains at Joliet and the Illinois river at Peru. Chicago was then a small city and no thought or attempt was made to transport the sewage of the city through this small artificial channel about six feet in depth and sixty feet in width. In fact, the city was too far removed from it and the sewage disposal system had been devised and started so as to force it into the lake, the natural basin of the watershed. The Illinois and Michigan Canal was constructed and used for navigation purposes. It remained in this condition from 1850 to 1871, when the flow became so low that navigation was impeded. The stock yards had been established south of the city on the south fork of the south branch of the Chicago river and north of Calumet river. The population of the city did not at that time extend into this district to any considerable extent. The South Fork at this point was a very sluggish stream; in fact, it consisted of practically an artificial slip constructed and devised to carry away the washings from the stock pens and yards. It soon assumed a stagnant condition and so remained, having no effect upon the main body of the Chicago river and consequently poorly discharged the purpose of its preservation. Pumping works were established at Bridgeport for the purpose of lifting the contents

of the South Fork at the stock yards into the canal. Since then, during navigation seasons, about 10,000 cubic feet per minute has been discharged from the South Fork into this canal. The effect of the discharge was to cause the canal to assume a sluggish, foul, stagnant, septic condition, calculated to destroy the few pathogenic bacteria that found their way into it. The sewage discharged into this canal at Bridgeport has always been largely from the stock yards, and therefore not of the dangerous sort that comes from the heart of the great city. It was deposited into the canal in its raw state, free from dilution, and therefore possessing all the elements and characteristics of a septic tank, aiding, assisting, advancing and inducing a high stage of putrefaction, chemical reduction and bacterial destruction. After having remained in the river for an indefinite period it was discharged into the canal (a septic tank so to speak), where it again remained for an indefinite time. During the winter months, when septic operation was less active, the pumps were closed. The filth and washings from the stock yards during the winter months either remained in the south fork of the river or were at times of heavy rainfalls and floods forced into the lake.

The small amount of matter conveyed through the Illinois and Michigan Canal is manifest from the fact that no observable effect was produced or had upon the quiescent and putrescent condition of the Chicago river. However, had this small amount of polluting material been discharged through a canal and down a stream diluted with Lake Michigan water at the rate of 1,250,000 gallons per minute, the preservative influence upon the pathogenic substances contained in it might, and perhaps would, have become troublesome to people residing upon the stream at points below the initial discharge, and produced sickness and death among those using and drinking of the water.

The Des Plains river is a small stream having its source in the State of Wisconsin, passing down through the northern portion of Illinois at a distance of about ten or twenty miles from Lake Michigan until it reaches Joliet, near where, in connection with the Kankakee, coming from Northern Indiana. the Illinois is formed. During a great portion of the dry seasons

of the year, the Des Plains is small and has practically no current whatever. During flood times, the water spreads over the territory near its mouth and runs into the Chicago river, driving sediment and infectious material from the Chicago river far out into Lake Michigan. Since the opening of the drainage canal, however, this condition has occurred but once.

The canal of the Sanitary District of Chicago was constructed by authority from the defendant state for the purpose of relieveing the serious conditions which confronted the city of Chicago with reference to its water supply. The conditions affecting the drinking water of that city had become steadily worse from the days it became a city and conditions were such that the public generally became much concerned and determined to devise some means by which the city could be relieved. This resulted in the organization of the corporation known as "The Sanitary District of Chicago."

The channel was then constructed from the southern branch of the Chicago river to the Des Plains river, a short distance above Joliet. It follows the general location of the old Illinois and Michigan Canal from Chicago to Lockport, and traverses the territory partly tributary to Lake Michigan and partly tributary to the Mississippi river, connecting with the Chicago river at Robey street in the city of Chicago, it runs southwestwardly, crossing the divide between Lake Michigan and the Mississippi river watersheds near what is termed the summit range line; an imaginary line dividing or separating the watershed of Lake Michigan from that of the Mississippi.

The first seven or eight miles of the channel passes through clay formation readily dredged. It is 110 feet wide on the bottom, with slopes one foot vertical to one foot horizontal, giving a surface width of 198 feet and a minimum depth of water 22 feet. At the end of this stretch of channel, a glacial formation is passed through. The full size of the channel through this glacial portion is 202 feet wide on the bottom, with sides slope of two feet horizontal to one foot vertical, resulting in a channel of 290 feet wide on the surface, with a minimum depth of 22 feet. Seven miles of the distance consists of a cut through solid rock, the sides being cut practically vertical. The uniform

width of the channel throughout this distance is 162 feet, with a depth of 22 feet.

The controlling works are located at Lockport and consists of seven lifting gates and one bear trap dam. Each gate has an opening of 32 feet and is worked and counterbalanced by winces so constructed that two men can raise and lower them under pressure, although the gates themselves weigh 62,000 pounds. It was necessary to construct this dam or controlling works in order to be able to, at all times, control the volume of water passing through the channel.

The Chicago river had been discharging the sewage of Chicago into Lake Michigan for a number of years. This discharge polluted and infected the waters of Lake Michigan for a distance of several miles, the intakes of the Chicago water works being located out in the lake at a distance of from two to six miles from the shore. It was deemed more advisable by defendant to dispose of the sewage of the city through an artificial channel into the Mississippi river watershed than undertake the expense of extending the intakes of the water works system into the lake sufficient distances to be free of the contamination of the city at all times of the year. This is a significant fact when it is considered along with the proposition that Lake Michigan is practically a quiescent body of water. It is also the more deeply significant, as applicable to this litigation, when it is remembered that no concern whatever was given to the unfavorable injurious and damaging effect upon complainant's people and property. This inhuman conduct is intensely aggravated by defendant's knowledge that by the use of proper modern appliances for a comparatively inexpensive treatment of sewage, the injurious and infectious substances and organisms could have been successfully removed from the sewage of the district before being discharged into the water supply of the people residing upon an adjoining watershed.

Commencing on the Illinois river at Joliet, the following tributaries enter into it between that point and its mouth at Grafton: Des Plains, DuPage, Kankakee, Fox, Vermillion, Mackinaw, Spoon, Sangamon, Crooked Creek, Macoupin Creek,

McKee's Creek. All of these tributaries are small, having comparatively small drainage areas.

Passing down the Illinois river from Joliet, there is a rapid fall in the channel from Dam No. 1 to the head of Lake Joliet, which is three and one-half miles southwestwardly. The fall in this distance is 21 feet. Lake Joliet, so called, is a widening of the stream to probably one-half mile, with something near five miles in length. For a distance of about one mile from the mouth of what is called Lake Joliet, the fall is nearly ten feet. From this point, the fall is gradual until the Marseilles dam is reached. The effect of the Marseilles dam upon the waters of the river prior to the opening of the channel was apparent for about 20 miles, the water being backed above Marseilles that distance. The fall at the dam is 12 feet. At Ottawa, about 8 miles from Marseilles, Fox river enters and the fall becomes gradual from this point to Peru at the head of the backwater from the dam at Henry 29 miles below. The next dam below Henry is what is known as Copperas Creek, a distance of 59 miles. Between Copperas Creek dam and Henry dam, the river forms what is known as Lake Peoria, a larger body of water, varying in width on an average of a mile and three quarters to eight and ten miles in length; it is simply an enlargement of the river. LaGrange dam is 58 miles below Copperas Creek, while Campsville dam is 48 miles below LaGrange. Of these dams, the latter two were constructed by the United States Government in aid of navigation. The others were built by the State of Illinois.

Prior to the opening of the drainage canal, these dams caused the water to remain in practically a quiescent state during the greater part of the year, so much so that a green algae formation was observed during the summer months on the surface of the river. This formation constituted evidence of the destruction of the nitrogenous matter contained in the water, and of the process of self-purification constantly taking place, it being agreed by all the witnesses who testified in the case that water in a quiescent condition would more readily purify itself of its polluting material than when existing in a swift, running stream. The fishermen who lived on the Illinois river testified

that during the greater portion of the year there was no perceivable current; that a chunk thrown in the water would remain where deposited unless driver by the wind. This was the condition of the river both above and below the respective dams prior to January 17, 1900. Subsequent to the date of the opening of the drainage canal, there has been a continuous current from the source of the river to its mouth at Grafton. The dams have no consequential retarding effect upon the current. The green algae scum has disappeared, although it is a known fact that there remains in the water more of the constitutent elements which form or produce the algae if a quiescent state could be obtained. In fact, more of the polluting and infectious material is now contained in the water than prior to the opening of the drainage canal; thus showing an extensive prolongation of the life of disease producing organisms under conditions now existing as compared to conditions prior to 1900.

For the purpose of this case, velocity observations on the water of the Illinois river from Chicago to Illinois were made by Professor Vanornum of Washington University, St. Louis, on the part of the complainant, and by Mr. Randolph, engineer in charge for the Sanitary District of Chicago, on the part of the defendants. Prof. Vanornum's observations were made during the spring season, while those of Mr. Randolph were conducted during the summer and autumn season. Mr. Vanornum's observations disclose that the water passed from the Chicago river at Chicago to the intake tower of the St. Louis water works at the Chain of Rocks in 9 days and three minutes, while Mr. Randolph's determinations show a time limit of a few minutes less than 15 days. The minimum flow of the river may be designated as about 8 days and the maximum flow at 18 days with a mean velocity from Chicago to St. Louis of probably 10, at any rate not more than 12 days.

In passing judgment upon the sanitary condition of a water supply, the science of chemistry has long occupied an important position, while the science of bacteriology has also for some years claimed an important position in this connection. Chemists have determined, in a general way, that the chemical conditions of a polluted water may by long experience be character-

ized as follows: First, high free ammonia, high nitrites, high chlorine indicate sewage pollution. The foregoing is, of course, conditioned upon the hypothesis that the watershed of the stream examined is polluted and that there are no salt bodies of importance traversed or drained by the river. Second, high free ammonia, high nitrites and high chlorine with low nitrates indicate sewage pollution in its earlier stages. Third, high free ammonia and low nitrites with high chlorine indicate vegetable pollution with salt bodies located upon the watershed of the river. Fourth, low free ammonia, low nitrites and high chlorine and high nitrates indicate that the water examined may have been sewage polluted, but has remained in a quiescent condition a sufficient length of time and under such favorable circumstances as to largely reduce the organic matter therein contained and to some extent free it from its former polluting substance. It, however, does not necessarily indicate that disease producing organisms or pathogenic bacteria have disappeared.

According to the science of bacteriology, it is practically impossible to discover in a contaminated water the disease producing organisms; so small are the organisms and so delicate the test to be made. It has, however, been observed, that where large quantities of bacilla coli communis have been found, it is a conclusive indication that the water is sewage polluted and, therefore, infected with disease producing organisms. The number of bacteria is important if the source of the polluting matter is known. However, bacteriologists when applying the science to the sanitary observations of water, disregard largely the number of bacteria and depend mostly upon the character of the pathogenic organisms found.

Typhoid bacilli, the most dangerous perhaps of any of the water-borne diseases, has never been discovered in the waters of a running stream, save as to two or three reported instances, and from the present conditions of the science, their discovery is not a practical proposition. So it may be said that from the standpoint of bacteriology and chemistry as applied to sanitary observations, there is no direct means of proving the absolute presence of pathogenic bacteria in water. A water supply may be chemically without fault and yet contain many living disease

producing organisms. Or it may contain large quantities of organic nitrogenous substances so as to be condemned by the chemist, and yet contain no harmful substances; so likewise it may contain only a small number of bacteria, and be, therefore, not condemned by the bacteriologist, yet there frequently exists in such water sufficient pathogenic bacteria to produce an epidemic of typhoid among those who use it. It may be condemned by the bacteriologist as unfit for domestic use on account of the large number of bacteria, while as a matter of fact it is harmless and may be used with impunity.

The undisputed evidence, admitted by expert witnesses on behalf of defendants, show that in the chemical observations of a water supply the controlling factors depend upon the total amount of the organic nitrogenous matter contained in it. That this nitrogenous matter contains substances, some of which are decomposing in character and others, under the test of bacterial chemistry, consist of living micro-organisms. No plan has yet been devised to determine the exact character of the organisms from a chemical standpoint. The intricate process employed by bacteriologists is such that the observer is permanently arrested in his attempt to separate the various living micro-organisms in the water to such an extent as to enable him to say of a certainty that no particular disease producing organisms exist in it. Sufficient discoveries have been made, however, to enable an expert sanitarian to say with full confidence that each organism, like the human being, is endowed by nature with a distinct and separate existence or life. Some are frail and some exceedingly strong with highly vitalized powers. Some multiply in living natural water and others do not. The general belief as to pathogenic bacteria is that they do not multiply or propagate in natural water, their ability to increase depending upon an introduction into the human system or a suitable media especially prepared. This may be stated as a general rule, and is followed by nearly every prominent and competent observer. It is not known that pathogenic bacteria feed upon anything while contained in living or polluted water, though some observers are inclined to that view. Not being dependent upon other forms of bacterial life for their sustenance, it is believed

they live and spend their existence independent of their companions, having at least an equal chance with them till they have perished from a gradual loss of vitality. Unless they sooner find their way into the system of some susceptible person where conditions are favorable for growth and multiplication. It is natural to expect them to possess a stronger vitality than the ordinary saprophytic bacteria, for with the latter when the field of their prey has become harvested their life task is completed. While the pathogenic bacteria, or the so-called parasite, being highly vitalized, as competent bacteriologists have observed, lives for a considerable time either in the presence or absence of nitrogenous compounds. Independent of other forms of bacterial life and largely capable of seeking agreeable conditions and surroundings (being motile) the conclusion comes as an unimpeachable certainty that as saprophytic influences are destrowed by dilution or by a removal of the nitrogenous compounds, the life of the parasite is thereby prolonged.

Laboratory experiments have been made as to the longevity of typhoid germs in various samples of water collected from various streams. Mr. Hiram F. Mills, for a long time chairman of the Board of Health of the State of Massachusetts, collected samples of water from the Merrimac river and deposited typhoid bacilli therein for the purpose of determining, if possible, both the longevity of the germs and their percentage of decrease from day to day. It was discovered by him that they would live in a laboratory while contained in the waters taken from the Merrimac river for a period of 27 days, gradually reducing, of course, from the first day. From these observations made by him he prepared a table which represents the percentage of immortality of typhoid fever germs in the waters of the Merrimac river. Since this discoverey, the table prepared by Mr. Mills has been used by scientists throughout the country in passing upon the sanitary conditions of water supplies and in determining the probability as to whether typhoid germs would pass from a given point where infectious material was being deposited in the stream to the intakes of the water supply.

Based upon this table, defendants introduced a chart showing the relative percentage of typhoid bacteria upon the Illinois

river watershed, including two millions of people from the city of Chicago, which would reach St. Louis within the life period of the germs. Basing the flow of the stream at 18 2-3 days from Chicago to St. Louis, it was found that the number of typhoid fever germs sufficiently vitalized to produce disease, which reach St. Louis within the time flow, would represent the total typhoid germs coming from the sewage of a city of 13,000 people situated immediately above the intakes at St. Louis on the Mississippi river. Based upon the mean flow of ten days, this determination results in the establishment of a city upon the Mississippi river immediately above the intakes at the Chain of Rocks of 162,000 population. In other words, the effect of the sewage of Chicago upon the waters of the Mississippi river at the mouth of the Illinois has been such as if a large and popular city was established on the 17th day of January, 1900, upon the banks of the Mississippi river discharging its sewage into the waters of that river.

The chemical analysis discloses that the water in the Illinois river at Grafton contains more infectious material, material liable to contain infection, than it did prior to the opening of the drainage canal. It also discloses that the waters of the Mississippi river above Grafton and the Missouri river are freer from contaminating and infectious matter than the waters of the Illinois. This, of course, is but a natural condition. The sewage of two millions of people could not have the effect of improving conditions at any point on the Illinois river. Keeping in view the enormous number of typhoid fever germs reaching the Mississippi at St. Louis from Chicago, based upon the table of typhoid bacilli longevity of Hiram F. Mills, as introduced by defendants, it is but natural that St. Louis and complainant should suffer, and continue to suffer from the evil effect of the discharge of raw sewage into the canal at Chicago. The average number of deaths from typhoid fever among the 2,000,000 people living in Chicago for the last 12 years has been 776 per annum. Multiplied by 15 (the experience of the country showing that for every death there are at least 15 cases of the disease), there may be said to have been 11,640 cases per annum. The germs from this large number of patients were

deposited in the sewage of the city and by it conveyed and discharged into the waters of the Chicago river, thereby seriously infecting the water which, when conveyed into Lake Michigan, rendered the water of the lake unsuitable for domestic purposes.

Knowing that by the opening of the Drainage Canal of the Sanitary District of Chicago the infectious material from this large city would be discharged into the Illinois river and from thence into the Mississippi a short distance above the intake tower of the St. Louis water works, and knowing that it would have a harmful effect upon the water of the Mississippi from Grafton to the southern boundary line of the State; that people using the water for drinking and domestic purposes would suffer evil effects therefrom; that water-borne diseases would be conveyed to them thereby and the water rendered objectionable from an esthetic standpoint, this suit was instituted to prevent the discharge of the unpurified sewage of the city of Chicago and the Sanitary District of Chicago into the Illinois river through and by means of the canal.

The city of St. Louis had but recently, at an enormous expense, removed its intake to the Chain of Rocks so as to secure the best quality of water obtainable. Large reservoirs, as heretofore stated, were constructed at this point for the purpose of allowing the water to settle and sediment for a period of from 24 to 36 hours before being distributed to the people for use. The result of this improvement reduced the number of deaths from typhoid fever materially over former years. In fact, the number of deaths occurring from the disease for the years 1895 to 1899, inclusive, was as follows: 1895, 106; 1896, 106; 1897, 125; 1898, 95; 1899, 130. The ratio of deaths from typhoid during the period to each 100,000 population of the city being 19.6; a condition which compared favorably with the general run of the large cities throughout the United States. Being much better than Chicago, Cleveland, Pittsburg, Philadelphia, Buffalo, Cincinnati, Louisville and other important cities. The ratio of deaths from the disease during these years was no greater in St. Louis than in Boston, a city which boasts of its good water supply.

As contemplated by complainant as soon as the canal at Chicago was opened and the sewage of that city diverted to the Illinois and Mississippi rivers the death rate from typhoid in St. Louis started upward and has continued on the increase ever since. For the years 1900 to 1903, inclusive, the following number of such deaths occurred: 1900, 154 deaths; 1901, 181 deaths; 1902, 216 deaths; 1903, 281 deaths. The death rate from typhoid during this period per 100,000 population being 34.7. From the foregoing it will be observed that the typhoid mortality per 100,000 population in St. Louis for the years 1900, 1901, 1902 and 1903 increased 77.7 per cent over the typhoid mortality per 100,000 population in 1896-7-8 and 9. This enormous increase has occurred with no change in the manner of treating the water. The increase has been gradual, both in winter and summer seasons, with no relaxation in the least except that the percentage of increase has been greater in the winter seasons than during the summer months. All parts of the city where the public water supply has been used have alike suffered. No local epidemic has occurred; in fact, nothing has been observed, after a very searching investigation, that can in any way be charged with the cause of the increase save the discharge of the sewage of Chicago into the canal in question and hastening its flow to St. Louis by means of the Illinois river.

An attempt was made to show that this increase in typhoid in St. Louis since January, 1900, was due to the use of water from wells. The fact is that in those sanitary districts of the city having the greater number of wells there was less typhoid. For instance, District Number 2 with 1,073 wells suffered in 1900, 14 deaths from typhoid; in 1901, 27 deaths, and in 1902, 21 deaths. In District Number 7, with 1,877 wells, there were 23 deaths from typhoid in 1900, 30 deaths for 1901 and 25 deaths for 1902; while District Number 3, with only 101 wells, had 28 deaths from typhoid in 1900, 30 for 1901 and 36 deaths for 1902.

An examination was then made of conditions that existed at St. Charles, situated on the Missouri river about 40 miles from St. Louis, and Alton, Ill., on the Mississippi river, about 30 miles from St Louis. It was disclosed that in these cities there was no increase in typhoid since the opening of the drain-

age canal. The examination extended to all the principal cities upon the watersheds of the Mississippi, Missouri and Illinois rivers, where correct data could be obtained, and it was found that no apparent increase in deaths from typhoid had occurred upon the entire watershed of the Mississippi river above St. Louis, exclusive of the city of Chicago. Upon the Missouri river watershed, the typhoid mortality of the following cities for the years 1897 to 1902 was obtained: Lincoln, Omaha, Council Bluffs, St. Joseph and Kansas City, the cities of Jefferson City and St. Charles not being included for the reason that no mortality record existed prior to 1899. The total number of deaths per year occurring on this watershed, as shown by the mortality record of the above named cities, was as follows: 1897, 97 deaths; 1898, 118 deaths; 1899, 136 deaths; 1900, 108 deaths; 1901, 112 deaths; 1902, 109 deaths.

The Mississippi river watershed above the mouth of the Illinois was examined for the purpose of determining whether or not there had been an increase in typhoid in the respective years with the following results: 1897, 274 deaths; 1898, 252 deaths; 1899, 220 deaths; 1900, 256 deaths; 1901, 289 deaths; 1902, 202 deaths, the foregoing results being obtained from the mortality of the following cities on the above mentioned watershed: St. Paul, Minneapolis, Red Wing, Minnesota, Winona, LaCrosse, Dubuque, Clinton, Iowa, Rock Island, Moline, Davenport, Muscatine, Burlington, Keokuk, Quincy, Hannibal and Des Moines, the cities of Fort Madison, Iowa, and Louisiana, Missouri, being omitted for the reason that full statistics could not be obtained in reference to them.

Upon the Illinois river watershed, the following cities were examined for the purpose of determining the mortality record: Peoria, Bloomington, Ottawa, Decatur, Joliet, Elgin and Aurora, the cities of Springfield, Pekin and Havana being omitted for the reason that full reports could not be obtained. The totals for the respective years of these cities being as follows: 1897, 64 deaths; 1898, 66 deaths; 1899, 55 deaths; 1900, 107 deaths; 1901, 73 deaths; 1902, 70 deaths. The total results show the following number of cases occurring in the principal cities on the watershed of the Mississippi river above St. Louis for 1897

to 1902, inclusive, to be as follows: 1897, 435 deaths; 1898, 438 deaths; 1899, 411 deaths; 1900, 471 deaths; 1901, 474 deaths; 1902, 381 deaths, or an annual average for three years prior to the opening of the canal of 428 deaths and for the three years after the opening of the canal of 409 deaths.

With the great number of typhoid cases appearing annually in the city of Chicago, it is conclusive that the cause of the increase in St. Louis is due to discharge of the sewage of Chicago through the artificial canal constructed by the defendant, The Sanitary District of Chicago.

The effect of the canal upon typhoid conditions in the city of St. Louis is more apparent during the winter than the summer seaons. A comparison of conditions during the winter months of 1896-7-8 and 9 with the winter months of 1900-1-2 and 3, based upon the number of typhoid deaths in St. Louis per one hundred thousand population, shows an increase of 94.8 per cent, while during the summer months, an increase of 65.7 per cent. The increase in the total number of deaths in the city from typhoid, regardless of population, during 1900-1-2 and 3 as compared with the period of 1896 to 1899, inclusive, was 118.2 per cent during the winter months and 84 per cent during the summer months, while, as hereinbefore stated, the total increase per one hundred thousand population in typhoid fever deaths during the period prior to the opening of the canal as compared with the same length of time after the opening of the canal was 77.7 per cent; the total increase, regardless of population, being 95 per cent.

The evidence discloses the germs of tetanus (lock jaw) and anthrax to have been discovered in the waters of the Illinois river since the opening of the canal at Chicago.

It is but natural to believe that with a stream velocity of from 8 to 18 days from Chicago to St. Louis considerable infectious material finds its way to St. Louis. While it is true large numbers of the disease producing organisms perish on the journey, yet experience of the people at St. Louis shows that a considerable number pass through unharmed. This is in keeping with the declaration of Prof. Mason, one of defendant's witnesses, to the effect that "undoubtedly some of the more persist-

ent organisms retain their vitality throughout the journey." The fact that there has been a greater increase in the death rate from typhoid at St. Louis during the winter months is not surprising, for Chicago is noted for its winter typhoid, and it is admitted that the germs of typhoid live longer and consequently travel farther in cool weather than in warm.

The enormous increase in deaths and cases of typhoid in St. Louis caused by the discharge of sewage from the city of Chicago into the Mississippi has been a source of financial loss to complainant. It has been truthfully said that "The average city of 100,000 population wastes perhaps half a million dollars, per year on the luxury of having it." Not only is it a long, tedious and grave illness, often leaving life-long disabilities in its wake, but it is also one of the most expensive of ailments.

Counting each death in the city of St. Louis caused by the sewage from Chicago as having a value of $5,000, the loss to complainant is no small matter. While if we take into consideration the cost and expense of treating and nursing those cases wherein a recovery is had, together with the loss of labor while ill, the loss to the communty reaches a total of many hundred thousand dollars per annum. This is the finacial loss. The sorrows of death, pains of sickness and mental distress cannot, from the standpoint of humanity, be measured in dollars and cents.

Prior to the opening of the drainage canal, the passage of the sewage infected material from Chicago river into Lake Michigan created typhoid conditions in Chicago bordering upon an epidemic at almost all seasons of the year. This occurred regardless of the fact that the city continually from year to year extended its water intakes a greater distance towards the middle of the lake, some of the cribs being located six miles from the lake-shore. Observing that the water of the lake is in practically a quiescent condition during a greater portion of the time and that typhoid germs pass from the river a distance of several miles to the intake in sufficient time to remain virulent and vitalized after passing into the water supply, and thence distributed to the citizens, is not an unreasonable disclosure to find them passing down the rivers to St. Louis; the distance

traversed being governed largely by the longevity of the germ and the velocity of the stream. Typhoid organisms are shown to live in laboratory observations for a period varying from thirty to ninety days in living water. It is true the saprophytic influences upon the parasites, or disease producing organisms, contained in sewage is considerable, yet scientists have observed the presence of typhoid fever germs in raw sewage for a period of from seven to nine days. The dilution of sewage with water has a tendency to largely destroy the saprophytic influences in that it removes the parasites a greater distance from evil influences and effect, thus encouraging their life. By the addition of 250,000 cubic feet, or 1,625,000 gallons per minute, of water passing from Lake Michigan into the canal, the effect produced upon the disease producing organisms coming from the sewers of Chicago is such as to extensively prolong their life. By this means, they are enabled to travel a greater distance down the Illinois and Mississippi rivers than under conditions which existed in the Chicago river prior to the opening of the canal. Before the canal was opened, the sewage of Chicago was discharged into the river, which was then, practically speaking, a large septic tank. The natural outlet of this river is Lake Michigan. The contents of the river remained in a quiescent condition a greater part of the year and were seldom discharged into the lake except during high rainfall periods and freshets. When these took place, the river was gulched into the lake and this produced an evil effect upon the health of the people residing in the city. While the river remained in this stagnant, putrefied condition, its contents were broken up by aerobic influences and finally by anaerobic action became largely exempt from infectious organisms, yet, the observation of scientists upon conditions at Chicago were such as to lead them to believe that sufficient pathogenic bacteria remained in the putrefying mass in the river to create unfavorable conditions in the water supply of Chicago and to cause an abnormal mortality death rate from typhoid fever in that city.

Under present conditions, the germs of disease are deposited into the channel at Chicago, and from thence pass down the

Des Plains and Illinois rivers and the Mississippi to and below St. Louis uninterrupted and under atmospheric and physical surroundings such as tend to prolong their life rather than retard it.

The fact that disease producing organisms pass from Chicago to St. Louis is conclusively demonstrated when reference is had to a long list of typhoid epidemics that have occurred in Europe and this country in recent years. In nearly every instance, the epidemic has been caused by the infection of the water supply at some point above the intake, the distance in each instance varying to a considerable extent.

At Luzon, Switzerland, in 1872, the epidemic, after investigation, was found to be caused by the infection of a brook which passed through the mountain for a distance of one mile, the infection evidently occurring before the water had started through the mountain, its natural filtration plant. So perfect was the natural filter provided for by the mountain, that large quantities of flour were deposited in the stream above, but no evidence of starchy formation or of the flour could be detected at the brook. A number of barrels of salt were deposited in the water immediately before it started through the mountain, the water in the brook being examined a short time afterwards, was found to contain chlorine, or saline substances, demonstrating that the water in the brook came from the infected source. While the filtration was sufficient to protect it against the passage of flour or its entrance into the brook it was not sufficient to prevent the passage of typhoid fever germs.

Plymouth, Massachusetts, is another instance of an epidemic due to the infectious condition of the water supply. Lowell, Massachusetts; Windsor, Vermont; Pittsburg, Pennsylvania; New Haven, Connecticut, and other points suffered severe epidemics from the same cause, while at Detroit, Michigan, in 1892, a severe epidemic of typhoid fever occurred, which, after careful and continued observations, was traced to dredging by the government from deposits at the mouth of Black river, a distance of 57 miles above Detroit, with St. Clair lake lying between the two points. The time required for the water to flow from Port Huron, at the mouth of Black river, to Detroit, after

a careful observation by Mr. Gardner S. Williams, was found to be about thirteen days.

Washington City, D. C., has suffered enormous loss from typhoid fever. Only a fey years ago an epidemic broke out in the city. So prevalent was the disease that it became alarming. Investigation of the cause made it clear that the water of the city was infected by the discharge of typhoid laden sewage in the Cumberland river 150 miles above the city.

At Pittsburg, Pa., in 1898, the typhoid germs are known to have traveled in the water of the river from Oil City, a distance of 110 miles, in sufficient numbers to cause an epidemic of the disease.

At Buffalo, N. Y., the water supply is infected, although it is drawn from what might be termed the mouth of Lake Erie, having passed down one of the most favorable streams in the world from the standpoint of dilution, aeration, oxidation and similar processes.

Niagara river is an enormously large stream, Niagara Falls filters its water, but so imperfect is the filtration process that typhoid conditions are always high in this city.

It is a well-known fact that at Covington, Kentucky, and New Albany, Indiana, the water for domestic purposes is conveyed into large reservoirs and there contained for a period of thirty days before being distributed to the people for use; and yet, after its long wait in the supply basins, sufficient typhoid fever germs survive to produce an enormous typhoid mortality in the respective cities. With these facts before us, it is demonstrated beyond all human probability that the disease producing germs will and do pass from Chicago to St. Louis under present conditions.

Prior to the opening of the Chicago drainage canal, the five dams which have been constructed across the Illinois river, acted as barriers to the progress of the water and created large sedimentation basins by which a great portion of the bacterial contents of the water in the river passed to the bed and there remained until perished or until some freshet or increased volume of water had carried them further down stream. In other words, the process of sedimentation, as well as the process

of septic operation as hereinbefore mentioned, was more proficient prior to the opening of the canal than subsequent thereto, the dams of the river now being entirely insufficient to retard the water to any considerable extent as it passes down stream.

Living organisms contained in the waters of Lake Michigan are natural habitants thereof, but not found in the waters of the Missouri, Upper Mississippi or the tributaries of the Illinois, were discovered by the analists in the waters of the canal, the Illinois and the Mississippi river below Grafton, thus showing conclusively the discharge of living organisms from Lake Michigan to St. Louis. One hundred and seven barrels of bacilli prodigiosus containing one thousand million bacteria per cubic centimeter were deposited in the drainage canal at Chicago. Within the ordinary time flow from Chicago to Grafton to St. Louis, bacilli prodigiosus were discovered in samples of water collected from the Illinois river at Grafton and the Mississippi river at the Chain of Rocks. This is important when considered along with the well known proposition that this particular bacilli is not a natural habitant of any of the waters of this country. It is not found in the waters of Lake Michigan, the Illinois, Missouri or Mississippi rivers or their tributaries. Again showing conclusively that living organisms will and do pass from the great lake to the Mississippi by means of the artificial waterway. It is also a conceded fact that the life of the bacilli prodigiosus is similar in point of duration to that of the bacilli typhosus, or typhoid fever germs.

In addition to the constantly increasing infection of the river from the sewers of Chicago, it is an admitted fact that the increased volume and flow of the water caused by the discharge of 250,000 cu. ft. per minute through the canal quickens the passages of disease producing organisms from Havana, Pekin, Peoria, LaSalle and Joliet to the Mississippi river and to St. Louis.

It is necessary to take into consideration the combined urban population residing upon the watershed of a river in order to express an opinion as to the sanitary condition of the water of the river at any given point.

The population residing upon the natural watershed of the

Illinois river brands it as more heavily infected than either the Mississippi or Missouri river. Physical and atmospherical conditions also must not be overlooked.

The population upon the watershed of the Mississippi river has already burdened it with an immense sewage disposal. As population increases, the burden will become the more burdensome to those municipalities which are compelled to use the water of the river for domestic purposes. The time is not far distant when much trouble will arise in this connection, making it impossible to secure suitable water without very expensive treatment and improvement plants. The discharge of the sewage from Chicago into the drainage basin of the Mississippi has not only hastened that condition, but if not restrained, will compel St. Louis to spend many million dollars in the construction of a filter plant in order to force its typhoid mortality back to conditions similar to 1896-1897-1898 and 1899. The danger and damage to complainant, the menace to its welfare, the loss of its reputation as a city of comparatively low typhoid mortality and the impediment to its financial and industrial growth caused by the injury sustained and the constantly increasing embarrassing conditions manifestly convict defendants of the injuries complained of, and unquestionably warrant the decree so earnestly requested.

Much might be said of what may be expected in the future, as shown by the evidence in the case, if present conditions are permitted to become permanent. Ere long we may depend on Chicago having a population of more than 5,000,000. That city will then, so to speak, be brought nearer to St. Louis, in so far as its contaminating effect upon the water supply is concerned. The volume of the water passing through the canal will be necessarily increased, thus hastening the flow down the river. We need not, however, look to future developments for grounds of relief, the existing conditions are amply sufficient. We have, in the foregoing, stated the facts as they exist in the record, without embelishment or color. Every statement made is fully supported by facts known and shown to exist.

QUALIFICATION OF WITNESSES.

A number of experienced witnesses testified in behalf of complainant. Fully substantiating complainant's position and conclusively showing great injury and damage to the State of Missouri by the operation of the canal of the Sanitary District of Chicago. They qualified as competent witnesses as follows:

DR. AMAND NICHOLAS RAVOLD testified on behalf of complainant and qualified as an expert Bacteriologist, as follows:

Dr. Ravold lives at No. 2806 Morgan street, St. Louis, Missouri, and has been a practicing physician in the city of St. Loius since 1881. Since 1885 he has been a professor of Bacteriology. In addition to the general work as a scientist he was in 1886 connected with the Shaw School of Botany at St. Louis as Assistant to Professor William Trelease at Washington University, a University of national reputation and standing. In 1887 he became a lecturer on Bacteriology in the Medical Department of Washington University, which was then known as the St. Louis Medical College. Later he was made Professor of Bacteriology in the Medical Department of Washington University, and continued in that position until 1902, when he resigned to go abroad. While he was connected with the St. Louis Medical College, as above stated, it was consolidated with and became a part of the Washington Universty, and known as the Medical Department of Washington University. Later, and during the time he was connected with the school, the Missouri Medical College was consolidated with the St. Louis Medical College, both now belonging to the Washington University and passing under the name of the Medical Department of Washington University. The Missouri Medical College was founded more than fifty years ago and the St. Louis Medical College was founded many years ago, both of which institutions were, at the time of their consolidation with Washington University, well known with national and state reputations, recognized throughout the world as first class institutions, giving to their students the highest possible education

upon subjects affecting the medical science. In the commencement of his work with these institutions, Dr. Ravold was placed in charge of the technical training of bacteriologists and during the entire period of his professional career, both as a practicing physician, as a scientist and as an instructor, he employed and followed the best known practical means of making bacteriological determinations. As a general rule, on experiments made in this case, he adopted and followed the methods laid down by the Bacteriological Department of the American Public Health Association, of which he was and now is a member. During all the time of his employment with the institution above mentioned, he was engaged in teaching bacteriology from the latter part of September until May of each year.

In addition to the above work Dr. Ravold was in 1894 employed by the City Health Department of the City Government of St. Louis to aid in the bacteriological work of the Health Department. His title was that of Consulting Bacteriologist. During this time he carried out experiments of the Department on Diseases known as tuberculosis, diphtheria, typhoid, blood posoning and various other diseases that came before the public for consideration, and to considerable extent investigated the subject of anti-toxin for diphtheria. During the time he was employed by the city government he continued his connection with Washington University.

(Printed testimony, Volume 1, pages 1 to 8.)

As positive proof of Dr. Ravold's qualifications to perform the duties devolved upon him in this investigation, a more complete understanding as to his fitness can be obtained by reading the first fifty-eight (58) pages of the printed testimony, which shows clearly his perfect acquaintance with the science of bacteriology in various forms and the kinds of bacteria, together with the name of the discoverer of each and the date of the discovery, as well as of the many peculiarities and characteristics of the respective bacteria.

In addition to his bacteriological work, Dr. Ravold lectured for a number of years upon Pathology and Hygiene in the Medical Department of Washington University of St. Louis, and by reason thereof, and of his careful study of the subject, he is

well acquainted with the sanitary conditions required of a water for domestic use and is acquainted with the history of the examination of the sanitary conditions and surroundings of the water supplies of the different cities of the world as connected with the epidemic of typhoid and cholera.

(Printed record, volume 1, pages 462-463.)

DR. WILLIAM C. TEICHMANN, at page 640 of the printed record, volume 1, qualified as a professional chemist, as follows:

Dr. Teichmann lives at No. 3624 Shaw Avenue, St. Louis, Missouri, and at the time of testifying occupied the office of City Chemist of the city of St. Louis, having occupied that position since April, 1893. He was therefore well acquainted with the chemical and bacteriological investigations of the waters of the Mississippi river, the Missouri river, the Illinois and Des Plains river, and the Chicago Drainage Canal, begun by authority of the city of St. Louis in 1899, continuing throughout 1900, 1901 and 1902. During all of this time he had charge of the Chemical Department of the investigation and organized the system for the collection of samples of water for the chemical analysis. He was ordered by the Health Commissioner of St. Louis to take samples of water for examination from the mouth of the Illinois river and the Illinois river itself, as well as from a point above the mouth of the Illinois river, and also between the mouth of the Illinois and the Chain of Rocks.

Dr. Teichmann was educated originally at Washington University, St. Louis, Missouri. He left Washington University in 1875 and in the fall of that year entered the Polytechnic College of Brunswich, Germany, where he studied the science of Chemistry from 1875 until the summer of 1879. In the fall of '79 he entered the University of Berlin at Berlin, Germany, where he studied chemistry and a number of other corresponding branches like history and literature for general educational purposes until 1881. In Berlin he studied under Professor Ferdinand Tiemann, who at that time was considered one of the leading authorities on water analysis, and the author of the well known standard work on water analysis.

In 1881 Dr. Teichmann entered the University at Liepsic,

where he remained until the spring of 1882, when he entered the University of Munich in Germany, and graduated as a doctor of philosphy in chemistry and history in the year 1885, having practically ten years of education as a chemist—six years of which was strictly confined to the study of chemistry from a practical standpoint. While he attended the University of Berlin his work was for the greater part confined to the study of the analysis of water under Professor Tiemann. In 1885 Dr. Teichman returned to this country, and in 1890 became private assistant to Professor Charles O. Curtman, Professor of Chemistry in the Missouri Medical College. In 1891 he became assistant instructor of Chemistry in the Missouri Medical College, which position he retained until 1895, and during this time he assisted in quite a number of water analyses. In 1893 he was appointed City Chemist of St. Louis, and has occupied that office continuously since. As City chemist his duties were multifold, consisting of analytical work for the Health Department, which included a constant analysis of well water and of cistern water, the analysis of disinfectants used by the Health Department, all kinds of medicines and articles of food purchased by the city institutions and for the Police Department. Also various analyses were made by him for the School Department and the Board of Education. He also performed analytic work for the Water Department by making daily analysis of the city supply.

(Printed record, volume 1, pages 640 to 649, inclusive.)

By reading the foregoing pages of the record, Dr. Teichman's qualification as an expert Chemist, qualified to testify with reference to the sanitary condition of the water supply of the water of St. Louis and the effect of the sewerage of Chicago upon the Mississippi river, will appear unquestioned.

PROFESSOR EDWARD H. KEISER, qualified as a witness on behalf of complainant as a professional chemist, as follows:

Professor Keiser had been occupying the position of Professor of Chemistry in Washington University of St. Louis, Mis-

souri, since the fall of 1899, coming to this position from Bryn Mawr College near Philadelphia, Pennsylvania. He occupied the position of professor in the last named institution for fourteen (14) years prior to his employment with Washington University. For about two years before this he was connected with Johns Hopkins at Baltimore as an instructor in Chemistry, and for two years prior thereto was a Fellow in Chemistry in Johns Hopkins University.

In 1880 was graduated from Swarthmore College, Pennsylvania, taking the degree of Bachelor of Science, and in 1881 there was conferred upon him by that institution the degree of Master of Science, in 1884 he took the degree of Doctor of Philosophy in Johns Hopkins University of Baltimore, and in the summer of 1884, he studied in Germany at Freidburg, in Saxony, and in 1887 in Gottingen University, and in 1894 he studied at Heidelberg, Germany. All of the time being engaged in and pursuing a careful study of the Science of Chemistry.

In January, 1900, he was employed by the Water Commissioner of St. Louis and the City Chemist of St. Louis to make certain examinations of the waters of the Mississippi, Missouri, Illinois and Des Plains rivers and the Chicago Drainage Canal. During all his work Professor Keiser's attention was particularly called to the analysis of water, and the adaptability of water for domestic use.

(Printed record, volume 1, pages 968, 969, 970 and 971.)

J. L. VAN ORNUM, qualified as a witness on behalf of complainant.

Mr. Van Ornum is a resident of the city of St. Louis, a civil engineer by profession, and at the time of testifying was Professor of Civil Engineering in Washington University, having been engaged in this profession since graduating in 1888, at the University of Wisconsin. He had been connected with Washington University as Professor of Civil Engineering for four years, prior to testifying and still occupies that position. Before connecting himself with the above named University he was engaged in the practice of his profession in different parts of the country, his work consisting of municipal and railway engineering and

work under the government on rivers and harbors. He spent two years in the service of the United States surveying the boundary line between this government and Mexico.

Mr. Van Ornum, during the month of March, 1903. determined by means of floats deposited in the water, the time required for water to flow from Lake Michigan to St. Louis. This work was done under the direct supervision and management of Mr. Van Ornum for the purposes of this case.
(Van Ornum's testimony, Vol. 2, pages 1732 to 1736, inclusive.)

GEORGE CHANDLER WHIPPLE, qualified as a witness on behalf of complainant, as follows:

Mr. Whipple is a resident of Brooklyn, New York. He is biologist and director of Mount Prospect Laboratory of the department of Water Supply, Gas and Electricity of the City of New York, having occupied that position since 1897. He was graduated from the Massachusetts Institute of Technology in 1889, taking a course of civil engineering. During the summer vacation previous to graduating he was Inspector of Tenement Houses in the city of Boston; after graduating he was employed for several months by the Superintendent of the Boston water works to perform certain experiments in the filtration of water through a sponge. In the fall of 1889 a biological laboratory was established by the Boston Water Department and Mr. Whipple was placed in charge of that work under the title of Biologist. His work in that laboratory consisted in the inspection of all the sources of water supply of the city of Boston, and in addition to the inspection of such sources, microscopical examinations of the waters were made. Those examinations consisted of, first, physical examinations; second, bacteriological examinations, and, third, chemical analyses of the various sources of supply. In connection with this work he made a test of the sewage disposal system at South Framingham, located upon the watershed above Boston. Similar examinations were made of the sewage disposal system of Natick, Mass., and frequent tests of Pegan Brook, in Natick, Mass. Inspection trips were made which covered all the large water supplies of Massachusetts for the purpose of comparing the water of Boston with those of the cities

tested. Frequent trips were made to the Lawrence experimental station, constructed by the Massachusetts State Board of Health, the object being to observe experiments carried on there. For three years he had charge of an experimental filter plant carried on in connection with the Biological Laboratory of Boston, and during the eight years he was connected with this laboratory, numerous experiments were made in the growth of microscopic organisms, upon the temperature of large bodies of water, particularly in regard to the so-called stagnation phenomenon. He assisted in designing an instrument called the thermopome, for obtaining the temperature of water at the bottom of reservoirs. From 1893 to 1896 he had charge of the Biological Laboratory under the direction of the Water Works of Lynn, Mass., where similar tests were made.

In 1896 four months were spent with Prof. Albert R. Leeds of Hoboken, New Jersey, where he assisted Prof. Leeds in studying the water of Brooklyn, New York, which at that time was affected with bad odors.

In 1897 he established a laboratory known as the Mount Prospect laboratory, in connection with the Brooklyn Water Department, having charge of its equipment and planning the work. The scope of this laboratory was extended after annexation of Brooklyn to the city of New York, and analyses of water made which included chemical, physical, microscopical and bacteriological tests, covering the Borough of Queens, as well as the Borough of Brooklyn. In January, 1903, the scope of this laboratory was further extended and now covers the entire water supplies of the city of New York. In connection with this work he has had various occasions to visit all the watersheds, to keep close lookout as to the presence of typhoid fever in the city, and in general watch the sanitary condition of the water supply, having in this way investigated a number of local epidemics of typhoid fever.

Early in 1903 he was appointed one of a commission to study the future supply of water for New York City, the commission being known as the Commission on Additional Water Supply. All the sanitary investigations involved in that problem were placed in his hands. Under his direction a temporary laboratory

was established at Poughkeepsie, and another at Katonah. The commission, under the supervision of Mr. Whipple, is making a careful study of all the sources of water supply that are available to the city, which includes practically all waters of the eastern part of the State. A careful study is being made of all streams that drain into the Hudson river, as well as the Hudson river itself. In connection with his laboratory work he has recently made a test of the electrozone process of purifying water, and is preparing a design for a sand filter to filter 15,000,000 gallons of water per day on the Croton watershed. In addition to the foregoing he is now making tests with a sand filter at Poughkeepsie, and carrying on experiments of sedimentation of water at Poughkeepsie, as well as studying the question of how far sea water runs up the Hudson river under different conditions.

In addition to the foregoing, Mr. Whipple has had considerable private experience as a sanitary expert, and during the last several years has examined waters from nearly every state east of the Mississippi river, from Cuba, Egypt and India. He has carried on a series of examinations of samples of water from Little Falls, New York; Watertown, New York; Oswego, New York; Birmingham, Alabama; Red River, Louisiana, and the Delaware river at Trenton; from the Susquehanna at Binghampton, and the Wabash at Vincennes, Indiana, and elsewhere. He has also made a report on the electrolic manner of water purification for the United States War Department, and is consulting chemist for the Water Department of Binghampton, New York, where a mechanical filter has been constructed which filters water at the rate of six million gallons per day, Mr. Whipple having had the practical charge of the operation of this filter during the past year. He investigated an epidemic of typhoid fever at Waterville, Maine, which extended also to the towns of Fairfield, Winslow and Benton. He is employed as sanitary expert for the Kennebec water district, and has published sixty to seventy pamphlets relating to water and sanitary matters, and is the author of a book on the microscopy of drinking water, the title being "Microscopy of Drinking Water, by George Chandler Whipple," which was published by John Wiley & Sons, in 1899.

Many experiments were made by him affecting the method of water analyses, as well as devising the so-called silica standard for the measurement of turbidity of water, which has been accepted by the United States Geographical Survey. He devised a scheme for tabulating odors which was accepted by the American Public Health Association.

Mr. Whipple is a member of the American Society of Civil Engineers, the American Chemical Society, the American Microscopical Society, the Society of American Bacteriologists, the American Public Health Association, of which he is Secretary of the laboratory section, and the Society of Chemical Industry. He is also a member of the American Limmological Commission, and Fellow of the Royal Microscopical Society of London, and Secretary of the Committee on Standard Methods of Water Analyses of the American Public Health Association.

The foregoing qualifications are to be found in Vol. 2, pages 1903 to 1908, in the record.

WILLIAM THOMPSON SEDGWICK, qualified on behalf of the complainant, substantially as follows:

Professor Sedgwick resides at Boston, Mass. He was graduated at the Sheffield Scientific School at Yale, in 1877, and studied for the greater part of two years in the Yale Medical School, taught physiological chemistry at Yale for one year, and became fellow, assistant and associate of Johns Hopkins University, Baltimore. He went to Boston in 1883 and since that time has been assistant professor, associate professor and professor in the Massachusetts Institute of Technology of Boston. Prof. Sedgwick received the degree of Doctor of Philosophy at Johns Hopkins in 1881. He served as biologist for the State Board of Health from 1888 to 1891, and is a member of the American Academy of Arts and Sciences, Massachusetts Associations Boards of Health, New England Water Works Association, Society of American Bacteriologists, American Society of Naturalists, American Public Health Association, Member of the Advisory Board of Hygiene, Laboratory of the United States, Public Health and Marine Hospital Service, Past President of the American Society of Naturalists and Society of

American Bacteriologists. He has been employed by various cities and towns as an expert on water supply or sewage disposal; especially at Burlington, Vermont; Pittsburg, Penn.; Lowell, Mass., and other places. He is the author of a text-book on Biology, a treatise on the Principles of Sanitary Science and Public Health, published in 1902, and has made numerous reports of investigations of epidemics of typhiod fever for the State Board of Health of Massachusetts, also a report on typhoid fever in Pittsburg in 1898. Prof. Sedgwick has published numerous papers on water supply, water purification and sewage purification, besides a paper on typhoid fever in Chicago in 1902, in connection with Allen Hazen, the well known sanitary engineer. He is a biologist, bacteriologist and epidemiologist.

(Sedgwick's testimony, Vol. 3, pages 2184 and 2185.)

GARDNER STEWART WILLIAMS, qualified as witness for complainant, as follows:

Mr. Williams lives at Ithica, New York, his present occupation being that of consulting water supply and hydraulic engineer, and Professor of Experimental Hydraulics in Cornell University, having been connected with Cornell University in the above capacity since 1898. He was educated in the high schools of the State of Michigan, and in the Engineering Department of the University of Michigan, taking the degree of Bachelor of Science and Civil Engineering in 1887; in 1889 the advanced degree of Civil Engineering was awarded him as a result of his experience and study in connection with water supply from a sanitary standpoint, and the diseases likely to be communicated by them, and investigations made upon the flow of water. The results of some of these investigations were presented to the American Society of Civil Engineers during the past two years, and he received the Normal medal awarded by that Society.

Mr. Williams began his experience as a water supply engineer in connection with the construction of water works at Bismarck, N. D. At that time he was also in charge of the construction of water works in Greenville, Mich., and afterwards at Owosso, Mich. In 1893 he became civil engineer to the Board of Water Commissioners of the City of Detroit, in which posi-

tion he had the responsible charge of the design and construction of all engineering work that was done in connection with the plant of the city of Detroit, which was then supplying between 270,000 and 300,000 people with water, and had a distributing system of between 400 and 500 miles. He retained this position until the fall of 1898. During those years he was engaged as consulting engineer in connection with numerous other plants, prepared plans and specifications and had supervision of construction work at several other places, and since that time has prepared plans for, and superintended the construction of extensive additions to the water works plant at Ithica, New York and is now consulting engineer of the Ithica Water Works Company. During the last ten years Mr. Williams has made the study of water supplies one of his principal occupations. The hydraulic laboratory of Cornell University has been under his direction and charge since the fall of 1898, and this laboratory is by far the most extensive hydraulic experimental station in the world. During the time he has had charge of that laboratory, expensive experiments have been carried on as to the flow of water in open channels and over dams. Part of those experiments have been made under and for the United States Board of Managers on Deep Waterways, and in connection with the Croton supply and in part in connection with the New York State Survey. At the time of testifying, Mr. Williams was engaged in extensive experiments for the United States Survey. In addition to the foregoing he has made a number of important investigations and experiments in the laboratory of Cornell. He has also been engaged in investigating the flow of water at Holyoke, Mass., Sault Ste. Marie, Mich., and the discharge of the Ste. Marie river at Sault Ste. Marie, Mich., and during his work at Detroit in connection with the Detroit Water Works he had occasion to make an extensive series of investigations on the flow of the American channel of the Detroit river, and on numerous occasions has investigated the problem of water flow. As a water supply engineer he has been closely identified with and interested in such diseases as are influenced by the quality of water used, and has made investigations of typhoid epidemics in Detroit, Saginaw

and Charlevoix, Mich.; Ithica, New York, and other places, and has extensively studied all information published in regard to epidemics of water borne diseases, both in this country and abroad, and to a considerable extent has made epidemiology a branch of his study in connection with water supply. (Record, Vol. 3, pages 2418 to 2420.)

GEORGE W. FULLER, qualified on behalf of complainants, substantially as follows:

Mr. Fuller is a resident of the City of New York, was educated at the Massachusetts Institute of Technology in Boston, and the University of Berlin, in Germany. While at the Massachusetts Institute of Technology he paid particular attention to the science of bacteriology, and also gave it considerable attention while at Berlin, both at the Hygienic Institute and in the private laboratory of the engineer in charge of the filter plant of the Berlin water works. He graduated from the Department of Chemistry in the Massachusetts School of Technology.

After returning from Europe and directly after his graduation he spent five years in the service of the State Board of Health of Massachusetts, and during the greater portion of his time was stationed at Lawrence, where an experimental plant has been established for the purpose of determining the best way of purifying sewage in water. During this time he was engaged in experimenting with water and the influence of sewage upon water. From Lawrence Mr. Fuller went to Louisville and Cincinnati, where he was engaged in studying the best means of purifying the waters of the Ohio river as found in the river at those places. He had charge of extensive studies and investigations, during which time at least $150,000 was spent under his immediate charge, for the purpose of ascertaining the character of the Ohio river water and the best means of purifying it.

For the past four years he has been in private practice as a sanitary engineer and expert, and has made investigations in upwards of twenty-five or thirty different cities, among which

is the city of Washington, D. C., where he was a member of the special committee appointed by the United States Senate committee of the District, which is in charge of treating the water of the Potamac river, the source of the water supply of that city. He was likewise engaged in Springfield, Mass.; Oswego, N. Y.; Meadville, Penn.; York, Penn., and Columbia, Penn., and through the group of cities lying directly west of New York, such as Paterson, N. J.; Passiac, Jersey City, Hoboken and others. He has also made extensive examinations in a number of places throughout the southern country, in Mexico, and on the far coast of Manzanillo.

Mr. Fuller is a member of the American Society of Civil Engineers, the American Chemical Society, the Society of American Bacteriologists, the American Public Health Association and the American Water Works Association. As a member of the American Public Health Association he has given work relating to water supplies of cities and towns considerable attention. For a number of years he has been chairman of the Committee of Purification of Water Supplies, and also of the committee having to do with the standard methods of water analysis.

(See Vol. 3, page 2602.)

ALLEN HAZEN, qualified on behalf of the complainant, as follows:

Mr. Hazen lives in New York City, his occupation being that of civil engineer. He resided in the City of New York for six years. He was born in New York and remained there until 1888, when he went to Massachusetts, where he remained until 1896, except one year, to wit, 1893, when he was engaged in work at Chicago. He was educated at the public schools of Hartford, Vermont, and the New Hampshire State College at Hanover; at the Thayers School of Civil Engineering, Hanover; the Massachusetts State Institute of Technology, and afterwards at the Technical School at Dresden, Germany. During his school years he studied chemistry, particularly the chemistry of water supply. He had direct charge of the Lawrence Experimental Station of the Massachusetts State Board of Health from the

time he left the Massachusetts State Institute of Technology until February, 1893. The character of his work at Lawrence was investigations as to methods of purifying sewage in water, and investigations of sanitary problems connected with water supplies and sewage. During the World's Columbian Exposition at Chicago he was in charge of the sewage disposal plant, and also had charge of the inspection of the drinking water used on the Fair Grounds. During his experiments and in his professional life he has been engaged in various undertakings. At Albany, New York, he advised regarding the water, particularly with reference to their supply and the means of improving it, and afterwards acted as engineer in charge of the construction of their water works. At Albany the death rate of the city was exceedingly high, and this high death rate was caused by the sewage polluted condition of the water. A plant was built for the purpose of filtering the water supply. At Ithica, New York, he is now engaged in building a filter plant. He built the filtration plant at Harrisburg, Pa., and at West Superior, Wisconsin, and is now designing a filter plant at Watertown, New York, and is also engaged in building a filter plant at Yonkers. At Pittsburg, Pa., he advised the city government as to the character of their water supply and the best means of supplying the city with pure and wholesome water, and afterwards made plans for a filter plant for the city.

He has carried on extensive investigations at Providence, R. I.; Chester, Pa.; Trenton, N. J.; Toledo, Ohio.; Grand Rapids, Mich.; Lancaster, Pa.; Millbury, Mass., and acted as consulting engineer for the Ohio State Board of Health; was engaged at Washington as a member of the commission composed of Messrs. Herring, Fuller and himself, which reported to the Senate committee of the United States on the water supply for the District of Columbia and the means of purifying it. More recently he has been engaged in the engineering corps at Washington with reference to the plans for the water works at that city, and has made plans for the filters of the city; the contract upon these plans has been let and the work begun.

Mr. Hazen worked with Prof. Sedgwick on the typhoid situation in Chicago in 1893, and after this work he secured ad-

ditional data, writing a paper jointly with Prof. Sedgwick upon typhoid conditions in Chicago. (See Vol. 3, pp. 2789 to 2796, inclusive.)

DR. EDWARD W. SAUNDERS, qualified for plaintiff, in rebuttal, as follows:

Dr. Saunders is a practicing physician at St. Louis, having been engaged in the profession there for 26 years; he attended and graduated from the University of Virginia in 1875, and since that time he has been practicing medicine in St. Louis, his office now being at No. 3007 Lafayette Avenue. (See record, Vol. 8, page 7857.)

DR. WASHINGTON E. FISCHEL, qualified as a witness in rebuttal for complainant, substantially as follows:

Dr. Fischel is a resident physician of the city of St. Louis, and has lived in this city all his life, and has practiced medicine since 1874; he is a graduate in medicine of St. Louis, Berlin and Vienna, graduating from the Washington University of St. Louis, the University of Berlin, and the University of Vienna. At the time of his graduation from the Washington University the department from which he was graduated was "St. Louis Medical College." At the time of testifying he was connected with the St. Louis Hospital in St. Louis, and was consultant to the City Hospital, and lecturing to the classes in that hospital once a week, his lectures being given on medicince, or that branch known as clinical medicine. Both he and Dr. Saunders qualified themselves as being well acquainted with the disease known as typhoid fever and other water borne diseases. (See Vol. 8, p. 7612.)

DR. LUDWIG BREMER, qualified as one of complainant's witnesses, substantially as follows:

Dr. Bremer resides at No. 3723 West Pine street, St. Louis, and is a practicing physician, having followed his profession in St. Louis for about 33 years. He studied at St. Louis Medical College, which is now known as the Washington University, from which he was graduated in 1870. After his graduation

he was connected with the city hospital of St. Louis, and later was resident physician of that hospital. He also studied at Strasburg and Zurich, Switzerland, and also at Paris on the subject of medicine. He also studied at Berlin and at Vienna, and has taught in the medical schools on the subjects of histology, pathologic anatomy, microscopy, biology and nervous diseases. Dr. Bremer is also credited with being the discoverer of the blood test for diabetes, and has written and published a number of medical and scientific articles. (See Vol. 8, p. 7623.)

DR. ALBERT E. TAUSSIG, qualified, as a witness in rebuttal for complainant, substantially as follows:

He has lived all of his life in St. Louis, and is now a practicing physician in that city. He has during his work served for one year in the City Hospital. His office is now at No. 2647 Washington avenue. He graduated from the Smith Academy, a branch of the Washington University, in St. Louis, and received the degree of Bachelor of Arts at Harvard University, then took the degree of M. D. at the Medical Department of the Washington University, and then served a year as interne at the city hospital and a year and a half in the University of Berlin, taking both clinical and laboratory work. He is lecturer in medicine and senior instructor in clinical chemistry and microscopy in the Medical Department of the Washington University, and chief of one of the two medical clinics in the same University, and is now on the staff of St. Luke's Hospital, one of the principal hospitals of the city. (Vol. 8, p. 7637.)

DR. CHARLES H. GOODMAN, qualified as a witness in rebuttal for the plaintiff, substantially as follows:

Dr. Goodman resides at No. 3329 Washington avenue, and is a physician by profession, having been educated in St. Louis and Philadelphia, and previous to receiving his professional degree he graduated at Yale University in 1867. He is a graduate of the Homeopathic Medical College of Missouri in St. Louis, and the Hahnemann Medical College in Philadelphia, having practiced in St. Louis for about thirty-five years. After having taught Theory and Practice for about five years in the Medical

College in Missouri, his position became for five years that of Professor of Theory and Practice. He is connected with the St. Louis Children's Hospital as attending physician and a member of the staff, and has been connected with this institution ever since its foundation, about twenty years ago. He has been a member of medical societies, local and outside, and is President of the City Medical Association, and the St. Louis Medical Association, the St. Louis Homeopathic Association, and enjoys a large and extensive private practice. (Vol. 8, p. 7657.)

DR. HERBERT E. SMITH, qualified for the complainants as a rebuttal witness, as follows:

Dr. Smith resides at New Haven, Connecticut, and is now Dean of the Yale Medical School, that is, the Medical Department of the Yale University. After the usual college preparatory course in the Hartford High School, he entered the Sheffield Scientific School of the Yale University, in the chemical and biological course, which is designed as a preparation for the study of medicine; then in the Medical Department of the Yale University he was laboratory assistant to Professor Benjamin Silliman. He then went to the University of Pennsylvania in Philadelphia, and received the degree of Doctor of Medicine in 1882. Immediately following he returned to Yale Medical School as laboratory assistant to Dr. Benjamin Silliman. At the end of that year he was appointed Lecturer in Chemistry in that department, and retained that position for three years, meanwhile doing, besides his teaching there, a certain amount of research work in chemistry in the Sheffield School, and also worked at Heidelberg, Germany, where he did some special work at the University there. After the death of Professor Silliman he was appointed Professor of Chemistry in the Medical Faculty of Yale, which position he still holds, shortly afterwards being appointed Dean of the Medical Faculty, which position he also still holds. In about the year of 1890 he was appointed by the Governor of the State of Connecticut as one of the State Chemists for Connecticut, and became interested in water works and water analytical work, as sisting the Connecticut State Board of Health in the work which

they were pursuing on rivers pollution in the State, and the examination of water supplies. After being associated with the Board for some time he was appointed Chemist of the Board and for fourteen years has had immediate charge of all the chemical and bacteriological work which the Board has done in connection with rivers pollution and examination of sewage and sewage effluent and drinking water. At Sheffield he received the degree of Bachelor of Philosophy. He has studied bacteriology, first becoming interested in this subject when he took up this branch of the work in 1887, and later, when bacteriology began to assume a considerable importance in connection with water supplies. He began to do personal work and has for a number of years done bacteriological work as it relates to the practical work of water examination. Dr. Smith was the first in this country to employ the use of the bacterial apparatus and methods which were originated by Dr. Koch, and is not only a chemist and bacteriologist, but thoroughly acquainted and familiar in a general way with the method and result of chemistry and bacteriology as applied to water and sewage. He has been called upon and appointed in a number of cases by the State Board of Health of Connecticut and elsewhere to investigate epidemics that have occurred at Waterbury, Conn.; Hartford, Conn.; North Manchester, Conn.; Stanford, Conn.; Branford, Conn.; New Haven, Conn.; Bristol, Conn.; Forestville, Norwalk and Danbury, and has quite frequently been consulted in the ways of small epidemics at various places. (See Vol. 8, p. 7679.)

JOHN W. ALVORD, qualified on behalf of the plaintiffs in rebuttal, substantially as follows:

Mr. Alvord is a sanitary and hydraulic engineer, residing in the city of Chicago, Illinois, having been connected with the practice of his profession for about 24 years, with Chicago as a center, and following his profession in that city and various parts of the country surrounding. Mr. Alvord was ready for entrance to the Sheffield Scientific School of Yale College in 1877, but was unable to take the course at that time owing to poor health, and his engineering course has therefore been con-

fined to study and travel, coupled with practical experience. The first engineering work in which he was engaged was in 1879 in Chicago, in connection with the construction of the Hyde Park Pumping Station of the Chicago Water Works and the Inlet Tunnel to such station under Lake Michigan. Later he was in charge of the operation of Lake View Station of the Chicago Water Works, and was for four years City Engineer of Lake View, which was then a separate municipality from the city of Chicago, since then annexed. After the annexation of Lake View to Chicago he was engaged in general practice in sanitary work in the suburbs of Chicago and adjacent cities. He visited Europe in 1888 and 1894 and examined the question of water purification and sewage disposal particularly. From 1890 to 1893 he had charge of a department in the construction of the World's Columbian Exposition at Chicago, and in 1894 resumed private practice, since which time he has been engaged in various capacities in about thirty-five different city waterworks plants, and about forty-five municipal sewer systems, including the purification of water supplies and the disposal of sewage. In 1898 he was engaged in making a report to the city of Columbus, Ohio, on the extension of its sewer system and the disposal of its sewage, which report was published. From 1898 to 1902 he was consulting engineer to the Illinois State Canal Commission, advising as to the works of the Sanitary District channel in and through Joliet and in the litigation as to the removal of dams and locks at Joliet. He has recently been engaged in the development of water power at Petoskey, Mich., and Big River, Missouri, and Des Moines, Iowa. He has also been engaged in the designing of some twelve waterworks plants which have been constructed and in which the question of river pollution bore an active part. He has had considerable experience in typhoid epidemics, having studied them at Hurley, Wisconsin, Ironwood, Michigan, and Culver Academy, Indiana, in 1894, and the typhoid epidemic of Chicago, in 1892, and 1893; the Duluth epidemic of 1896, the typhoid epidemic at Grand Forks, North Dakota, in 1894, and he was engaged to investigate the causes of the epidemic at Wequetonsing, Michigan, and Petoskey, Michigan, in

1903. He is well acquainted with the Chicago River, Chicago Drainage Canal, and the Illinois and Mississippi rivers. Mr. Alvord has given the question of bacteriology considerable attention in connection with his practice, and is also well acquainted with the science of chemistry as applied to water sanitation. He is a member of the American Association of Civil Engineers, and has been a member of that association since 1893, also a member and trustee of the American Society of Civil Engineers and Surveyors, a member of the American Waterworks Association, the New England Waterworks Association, and the American Public Health Association, serving this year (1904) upon its Committee of Water and Sewage Purificaton.

(See Vol. 8, pages 7761 to 7794, inc.)

E. E. LOCHRIDGE, qualified as a witness for plaintiff in rebuttal substantially as follows:

Mr. Lochridge lives at Boston, Mass., and after graduating from the High School at Elkhorn, Wisconsin, graduated from Beloit College, in which he pursued courses in science, giving particular attention to the study of chemistry, receiving the degree of Bachelor of Science in 1898. During his senior year he acted as private assistant to Professor E. G. Smith, and under his direction studied questions of water supply with special reference to the water supply of cities and towns. Immediately after graduating from Beloit College he served as instructor in Chemistry for two terms at Drury College, Springfield, Missouri. He then returned to Beloit, having been appointed a regular instructor in Chemistry in Beloit College, but again served a larger part of his time as private assistant to Professor E. G. Smith in further work on water supplies, mainly from a chemical point of view. In 1900 he took the regular and some special courses in bacteriology at the University of Chicago, in the department presided over by Prof. E. O. Jordan. He then resumed his duties as private assistant to Professor Smith. In the course of his work he has had occasion to visit many private and public water supplies, and to examine such supplies and to study and investigate several epidemics of typhoid

fever, among which may be mentioned those at Rock Island, Illinois, Baraboo, Wisconsin, and Ashland, Wisconsin, and has also studied the operation of filters for municipalities in a practical way at Davenport, Iowa, Ceder Rapids, Iowa, Rock Island, Illinois, Ashland, Wisconsin, Warren, Ohio, Kankakee, Illinois, Binghampton, New York, and two filter plants connected with the water supply of the Borough of Brooklyn, New York. During the years 1902 and 1903 he attended the Massachusetts Institute of Technology, in Boston, as a graduate student, taking the regular courses in sanitary engineering. He also, during his attendance at the Massachusetts Institute of Technology, in Boston, pursued advanced courses in bacteriology and sanitary science. In June, 1903, on the recommendation of Messrs. Samuel M. Gray and George W. Fuller, consulting engineers for the special commission on water supply of the city of Springfield, Massachusetts, he was appointed by that commission to make special studies on the question of purification of the water supply of that city. This work involved experimental investigation of the various methods of double filtration of water, and as resident engineer in charge of this work he had in his employ a number of trained assistants. (Vol. 8, p. 7821).

IMPORTANT AND ESSENTIAL FACTS SHOWN AND ESTABLISHED BY THE EVIDENCE.

On account of the extreme length of the record, we have deemed it proper to call the court's attention directly to the essential propositions established, which entitles complainant to the relief sought. While we might extend the abstract of the evidence so as to consist of a large number of printed pages, we feel that a more complete and direct understanding of the entire controversy and the controlling facts can be gained by compressing it as much as possible.

1.

WATER BORNE DISEASES.

Water borne diseases are produced by the effect of pathogenic micro-organisms upon the system of man or animal, and for convenience may be designated as

First: Typhoid Fever.

Second: Cholera.

Third: Dysentery.

Fourth: Vibrio Proteus, or a form of bacteria which produces a disease resembling cholera, but not true cholera.

Fifth: Bacilli Coli Communi, which may or may not be pathogenic, according to circumstances.

Sixth: Bacterium Tholoeideum, or a bacterium which before the application of the Weidal test produced a disease similar to typhoid fever. It is usually found in water suspected of causing typhoid fever, according to the statement of Dr. Frankland, a well known German scientist.

Seventh: Anthracis Spleenis. This Bacillus Anthracis or Spleenic Fever is among cattle, and as affects man producing malignant carbuncle.

Eighth: Proteus Vulgaris.

Ninth: Proteus Mirabili

Tenth: Proteus Zenkari

Eleventh: Proteus Fluorescens. This bacillus is said to be pathogenic to some lower animals.

Twelfth. Tuberculosis or Tubercle Bacillus.

Thirteen: Bacillus Tetanus, which produces lockjaw.

All of which, together with a few others of minor importance, are set forth at pages 887-888-889 of volume 1 of the printed testimony.

The principal water borne diseases may be designated as cholera, typhoid, dysentery, anthrax and tetanus, and the results produced by Bacillus Coli Communis when injected under the skin of a human being, or when lodged in the appendix producing appendicitis. Typhoid fever or Bacilli Typhosis is a

common water borne disease in this country. It is caused by crude sewerage being discharged into the water supply. This fact is demonstrated by the effect of the establishment of filtration plants for the purpose of treating the water supplied the cities of Hamburg, Germany; London, England, and Berlin, Germany, and in a number of large cities in this country.

(Printed record, volume 1, pages 446, 749-750-752.)

It is needless to discuss the question as to whether or not typhoid, cholera, dysentery, anthrax and tetanus are water borne diseases, as this proposition is conceded by the witnesses who testified on behalf of either side of the case. In fact sanitary science has come to realize with absolute assurance that the diseases above mentioned as a general thing are caused by inferior water, or water which has been subjected to sewerage pollution.

While it is practically impossible to discover or detect the physicial presence of bacillus in running water, save or except as to Bacilli Coli Communis, which is found in abundance in all streams in which sewerage is emptied. All persons having knowledge of sanitary science, have settled beyond question that the diseases above mentioned are as a general proposition more readily communicated by means of inferior water supplied than in any other way.

In the examinations of the water of the Illinois river the Bacillus of Tetanus and of Anthrax was discovered in the water of that river. This in connection with Bacilli Coli Communis which is very prevalent in the water of the Illinois, as shown by all the testimony in the case, constitutes practically the total results of the discoveries of the pathogenic bacillus in the waters of the rivers in question during this entire investigation.

2.

CHOLERA.

Cholera is known to be a germ disease, and was discovered in India in 1885 by Dr. Koch. In his investigation of the condition in India Dr. Koch found the cholera germ to be contained in the water of one of the tanks from which water was drawn

by the people for domestic purposes. He studied the germ under various laboratory conditions, and found that it would live an indefinite number of days in various kinds of water, subject to change of temperature. He found that it takes a temperature of boiling water to kill it, and that it will stand an indefinite period of freezing. While freezing will not destroy this germ, yet alternate thawing and freezing will eliminate a great many of them. The germ is highly active and belongs to that class known as motile or swimmers.

(Printed record, Volume 1, pages 28-29-30.)

It increases very rapidly in the human system, but no experiment so far shows that it multiplies in living water. It is a water borne disease, and is, therefore, contagious. It retains its vitality for quite a while when it is dried. It will float in the air after dried, and remain virulent for a long time. It infects the water supply and is communicated by that means to the people.

(Printed record, Volume 1, pages 48-49.)

3.

EPIDEMIC OF CHOLERA.

Dr. Ravold testified as to his familiarity with cholera epidemic at Hamburg, Germany, in 1892. The Jews were being driven from Russia and some of them settled on the quay at Hamburg, waiting for ships to transport them to the United States. There happened to be cholera among them and they remained upon the banks of the river Elbe, below the waterworks. The tide in the river carried the water from the point where they resided up stream, where it was conveyed into the intake of the Hamburg water supply. The unfiltered water was used for domestic purposes. In the course of several days about 18,000 cases of cholera developed. Altoona, a town situated immediately below Hamburg, perhaps about twenty miles, where the water is taken from the Elbe river below the sewers of Hamburg, Altona, nevertheless, was free from cholera, except among those who drank water in Hamburg and lived in Altoona.

Later a break occurred in one of Altoona's sand filters, and a flurry of cholera followed the break until it was corrected, when the disease disappeared.

This is one of the most beautiful examples in the world of water-borne diseases being carried by water supply. Professor Koch was called to Hamburg and studied the water supply of both places. He found the cholera bacilli in the water of the Elbe.

4.

TYPHOID FEVER, HOW CONTRACTED.

Typhoid fever is caused by a micro-organism, discovered by Ebert and Koch, independently, in the intestinal wall of persons dead of the disease, and later studied by Graffky, who had separated it out into pure cultures, so that it is known as the Koch-Ebert-Graffky bacillus, or the typhoid bacillus.

This micro-organism is found in the intestinal canal of people sick of the disease; in the fallicles and lympathics of the mucous membrane of the intestines; in the messenteric glands; in the spleen; in the liver; in the kidneys; flowing in the blood; sometimes in the rose spots or eruptions that occur on the skin; in the brain, and it is discharged from the body in the feces and in the urine.

No animal other than man suffers with typhoid fever, and in order for him to have the disease it must be taken into the intestinal canal, either through the mouth or through the nose, thence through the throat into the alimentary canal. In the alkaline fluids of the small intestines it finds a congenial habitat and grows and multiplies enormously, producing toxins, which coming in contact with the mucous membrane of the intestines, especially the mucous membrane near the lymphatic glands or the lymphatic tissues themselves, causes an exfoliation of the superficial cells, making a way for the entrance of the micro-organisms into the lymphatic stream and thus into the various organs above set forth, and in which the micro-organisms are usually found.

There are a variety of ways by which the bacillus typhosus is conveyed to the alimentary canal of man.

1st. By drinking water contaminated with the micro-organism.

2nd. The micro-organism may be contained in the dust that is blown around and thus conveyed through the nose.

3rd. By direct conveyance from sick to well persons nursing an individual sick of the disease. In handling the bed clothes, or soiled linen or other material about the patient attendants may have their hands inoculated with it and thus convey it into their mouth by picking their teeth, or picking their nose, or, without washing their hands, go to the table to eat and in this way convey it directly to their mouth.

4th. It may be carried in food, such as raw oysters fed at the mouth of a sewer. Conn of Wellesley showed that an epidemic of typhoid fever was produced by eating raw oysters which had been fed at the mouth of sewers.

5th. It may be conveyed by flies, as was shown to be the case among the soldiers in the typhoid epidemic that broke out among those stationed at Chickamauga and Jacksonville, Fla. It was there discovered that swarms of flies would feed in the latrines in which the dejecta of the men were thrown, and that as soon as the mess was served, the food cooked and served on the tables, the flies left the latrines in swarms and carroled all over the food of the soldiers, carrying the infective feces with them. Professor Vaughn, and others skilled in that line, who investigated the epidemic at that place, became convinced that flies were in a large measure instrumental in causing the epidemic, the bacilli being carried upon the feet of the flies from the latrines to the food upon the table.

6th. It is also conveyed by vegetable, such as lettuce or celery, sprinkled with water containing typhoid germs.

7th. Secondary infection: Where the germ finds its way into prepared food, such as potatoes, broth of all kinds and milk, which at the proper temperature causes them to increase and multiply very rapidly. In this way large numbers of the micro-organisms are taken into the system.

(Dr. Ravold's testimony, printed record, Volume 1, pages 830-832.)

The most active means of contracting typhoid fever is by the use of typhoid infected water for domestic and drinking purposes.

5.

TYPHOID FEVER EPIDEMICS.

One of the most satisfactory means of demonstrating the fact that typhoid fever is a water-borne disease is by a careful study of the various typhoid epidemics and an examination into the source of the infection.

ST. LOUIS.

Prior to 1892 the intake of the St. Louis water supply was at Bissell Point, which lies immediately north and above what now is known as the "Merchants' bridge." The sewerage from the city was discharged into a small stream immediately above Bissell Point. This stream is known as Harlem creek. A severe typhoid epidemic broke out in St. Louis in the early part of 1892. Upon investigation it was found that the sewerage from Harlem creek entered the Mississippi river about 1,000 feet above the intake at Bissell Point. This was observed by Dr. Ravold, according to his testimony in the printed record, Volume 1, page 408, where he said "black, oily looking water that was discharged from Harlem creek, ran into the yellow water of the Mississippi river at this point and could be seen floating down the river, clinging to the shore on the Missouri side, and could be seen at times running directly into the intake. I have stood on the bridge several times with other gentlemen—other physicians—and looked at it."

As soon as it was determined that the typhoid fever was caused by the water from Harlem creek flowing into the intake, a dam was constructed across the creek and pumps used for the

purpose of conveying the water into the Mississippi river, a point below the intake. As soon as this was done the typhoid epidemic at St. Louis for the year 1892 terminated. So severe was this epidemic that for the fiscal year ending in April, 1893, 3,624 cases of typhoid fever were reported to the health authorities by the physicians of the city, with a total number of deaths of 514.

(Printed record, Volume 1, page 410.)

LAUSEN.

At Lausen, Switzerland, an epidemic of typhoid fever occurred in August, 1872. Lausen is situated at the foot of Stockholm. It contained about seven hundred people. The water used for domestic purposes was obtained from a spring at the foot of this mountain. The water being conducted from the spring through pipes to the fountain in the town. In August, 1872, the first case of typhoid fever occurred in Lausen, and within a very short period 140 cases occurred. In the investigation it was found that Fuerlin brook was being discharged through the mountain as a natural filter, and that the water in the spring at Lausen had become slightly turbid and considerably increased in its flow. After a time this brook became again confined to its course and the hole that appeared in the side of the mountain was filled up. The brook being used in the summer time for irrigating the fields below. In June of that year a family, consisting of three persons, were afflicted with typhoid fever near the banks of Fuerlin brook; following this came the typhoid epidemic. Dr. Haegler undertook to discover whether or not the infected water passed down through this mountain to the spring below. In other words, whether the infected water from Fuerlin brook passed through the mountain to the spring. He put 5,000 pounds of salt in the hole and chloride of sodium was easily detected from the water which emptied into the spring. He also emptied several hundred pounds of flour into the brook, but none of it came through, there being no starchy particles detected in the water of the spring. It was also known that there was no typhoid fever in that district for

some sixty years before, except the three cases above referred to. The water carrying the typhoid fever germ was therefore required to pass through the mountain for a distance of about a mile, which it did and so thoroughly contaminated the water of the spring with typhoid fever as to cause the epidemic.

(Printed record, volume 1, pages 463-464-465.)

PLYMOUTH, PENNSYLVANIA.

In 1885 an epidemic of typhoid fever occurred at Plymouth, Pennsylvania, there being 1104 cases in the town, which contained a population with scarcely 8,000 inhabitants. Upon investigation it was found that this epidemic was caused by germs of the disease being discharged upon the banks of the reservoir, from which the water supply was obtained.

(Printed record, volume 1, pages 465-466.)

LAWRENCE, MASSACHUSETTS.

In 1896 an epidemic of typhoid fever broke out at Lawrence, Massachusetts. This was investigated by Professor W. T. Sedgwick, who arrived at the conclusion that the epidemic was caused by typhoid fever germs being discharged into the Merrimac river, from which the town obtained its water supply

(Printed record, volume 1, page 467.)

The Plymouth, Pennsylvania, epidemic is described by Prof. Sedgwick, as follows:

The most celebrated and important epidemic in this country was one which happened at a little mining town in Pennsylvania in 1885. On the watershed of that town they had built four storage reservoirs, and on the bank of the stream which supplied the uppermost of those reservoirs a case of typhoid fever appeared in the early spring of 1885. The reservoirs had all been drawn very low, owing to a cold spell which they had had, and on the arrival of the spring thaw, 1200 cases of typhoid fever broke out in this little town of 8,000 inhabitants. These were

traced—and it is believed by sanitarians were correctly traced—to the occurrence of the one case of typhoid fever on the banks of the uppermost reservoir, followed by the washing in during a thaw of the dejecta of that patient in the low stage of the reservoir and the rapid transmission to the people of that town. It was a dramatic and a terrible event. (Sedgwick's evidence, Vol. 3, page 2206.)

LOWELL.

In the autumn of 1890, Prof. Sedgwick was called to investigate an epidemic of typhoid fever in the city of Lowell, Mass. After preliminary study he was led to the conclusion that the epidemic in question was caused or had been caused by typhoid fever infection of a small sluggish stream which entered the Merrimac river, a larger and much swifter stream almost at right angles. It was found that the infection of the water of the smaller stream had mingled with the water of the larger stream so that at a point three miles below the entrance of the smaller into the larger stream where the city of Lowell had its intake, the infectious material was received, and from that place was borne into the water supply, producing an epidemic of over 1,000 cases of typhoid fever. While the epidemic was very severe at Lowell, it was also believed by the persons making the examination that it produced the epidemic at Lawrence, nine miles below. (Sedgwick's testimony, Vol. 3, pages 2200, 2201 and 2231.)

NEWBURYPORT.

This epidemic was caused by drinking typhoid infected water, twenty or thirty miles below Lowell. (See record, Vol. 3, page 2207.)

WINDSOR, VERMONT.

In 1892, or 1893, Prof. Sedgwick was sent to Windsor, Vermont, by the State Board of Health of Massachusetts to observe

the epidemic at that place. Windsor is a summer resort, and the water supply is derived from a dammed brook. The epidemic was occasioned by the typhoid ejecta of one patient upon the watershed above. (Record, Vol. 3, page 2208.)

PITTSBURG.

In 1898 a special study of typhoid fever was made at Pittsburg, Pa. Acting on the advice of one of the most eminent engineers of the time, Pittsburg introduced a water supply drawn from the Alleghany river mainly. The Alleghany river is a swift stream, with remote pollution, there being no near pollution of any moment. Oil City, 113 miles above, being the first important point which might be considered dangerous from the standpoint of typhoid infection. The result, however, of even that remote pollution was that after a careful study of the epidemic, prolonged for several weeks, a recommendation was made to the city of Pittsburg that a filtration plant be put in. (See Vol. 3, page 2208.)

NEW HAVEN, CONN.

Another serious epidemic, due to pollution on the watershed of a public water supply, is that of New Haven, Conn., in 1900. The city of New Haven obtains part of its water from a certain inhabited watershed, not thickly inhabited, but under conditions similar to those of Pittsburg, Pennsylvania. Their reservoirs had been drawn down low, owing to a freeze. In the spring a thaw came, which was followed by a big rain, with the result that typhoid micro-organisms were washed from a house on the watershed where there had been a few cases of typhoid fever. They were carried into the large storage reservoirs, resulting in 470 cases of typhoid during that spring. The cause of this typhoid epidemic was traced by Dr. Smith, Dean of Yale Medical College, and proved—as far as anything can be proved of this kind—that the probable cause of the epidemic was as above stated, by the germs of typhoid being carried into the reservoirs. (See Vol. 3, page 2209.)

DETROIT.

The water supply of the city of Detroit, Mich., is drawn from the American channel of the Detroit river. The intake is situated at the head of the river, or near the foot of Lake St. Clair. The water from Lake Huron enters St. Clair river, flows through it a distance of 35 miles to the delta of the St. Clair river, where it discharges into Lake St. Clair. Lake St. Clair is circular in form, being about 24 miles wide, including its delta, and 24 miles in length. The water supply of Detroit is taken practically from the lake, or from the river a few hundred feet below where it takes its origin in Lake St. Clair.

In the year 1890 the number of deaths in Detroit from typhoid fever were 39, and in 1892 the number rose to 209. This remarkable increase was such as to cause Detroit for that year to take rank among those cities which have had the highest death rate for typhoid fever in America. An examination of the records showed the epidemic began in June, during which month there were 38 deaths from typhoid fever. As civil engineer to the Board of Water Commissioners of Detroit, Mr. Gardner Williams commenced an investigation for the purpose, if possible, of determining the source of the remarkable infection. After an extended investigation he ascertained that the epidemic was caused by an improvement to the channel of Black river, which flows into St. Clair river near its head at Port Huron, a distance of 57 miles from the intake of the Detroit water works. Black river is a sluggish stream, having ordinarily no current, the current being perceptible only in times of heavy rain. For years the City of Port Huron had been discharging its sewage into Black river. In order to improve the harbor at Port Huron, the United States government had caused the river to be dredged during the early months of 1892. In the process of that dredging the deposits in the river near the mouth of the sewers had been removed, these deposits ranging in depth from one to eight feet. The material was loaded on scows, transported out into Lake St. Clair and in the St. Clair river, and there discharged or dumped into the stream. The investigation disclosed that this work was begun in such time and under such conditions that the infec-

tious deposit of material was dredged and deposited in the St. Clair river so as to fully explain the cause of the outbreak of typhoid fever in Detroit after having been carried through the waters of St. Clair river and through Lake St. Clair to the intake of the water works. St. Clair river at the point where the material was dumped is about 1800 feet wide and from 30 to 36 feet deep. It passed thence into Lake St. Clair, which has an average depth of about 16 feet, there being no perceptible current in the lake, though St. Clair river is quite a swift flowing stream. The time elapsing between the deposit of the infectious matter from Port Huron and the arrival of the water into which it was discharged, and the delivery of the same to the consumer in the city of Detroit would be the time required for water to flow from St. Clair river, where the deposit was made, to the intake in Detroit, and to be distributed throughout the city to consumers. Mr. Williams estimated this time carefully and found it could not be less than eight days, and not more than fourteen days, ten days being a fair estimate of the time required. According to the best evidence, the period of incubation of typhoid fever is from seven days to four weeks, seventy-five per cent of the cases, perhaps, incubating in from ten to fifteen days. It was found by making allowance for the time required for the infection to come from the point at Port Huron, where the material was discharged into the lake, to the consumers of water in the city of Detroit, allowing the average period of incubation for typhoid fever, and allowing the ordinary time to elapse between the taking down of the patient and the occurrence of death, that the sum of such times agreed within twenty-four hours of the time which had elapsed from the deposit of the dredged material from Black river into the St. Clair, and the occurrence in a single day of four deaths in Detroit from typhoid fever, there having been only one death in the preceding twenty-four days. (See Williams' testimony, Vol. 3, pages 2439 to 2445, inclusive.)

GRAND FORKS, NORTH DAKOTA.

The main sewer of the town of Crookston, Minn., became damaged in the fall of 1893, so that it failed to discharge the

material delivered into it. This led to the accumulation in the sewer of deposits of sewage matter, and to afford temporary relief a small connection was made around the break, which carried off a portion of the liquid matter of the sewage and discharged it into Red Lake river, which was the stream into which the sewage of Crookston was regularly discharged. In the fall of 1893 the sewers were repaired and on November 17th the sewage system of Crookston was flushed of the accumulations which had gathered during the several months preceding. Typhoid fever to the extent of about sixty cases had existed in Crookston in October and November, 1893. At the time of the flushing of the sewers and consequent delivery of the sedimentary accumulations from them into Red Lake river, the river was frozen over. The town of Grand Forks, North Dakota, is located about sixty miles by the river below Crookston, on Red river. In November there were in Grand Forks two cases of typhoid fever and no deaths, and for the month preceding there had been a very small amount of typhoid fever. In December following the flushing of the sewers in Crookston on November 17th, there were reported 230 cases of typhoid fever and four deaths in Grand Forks, in January 712 cases and 52 deaths; in February 231 cases and 27 deaths; in March 46 cases and 11 deaths; in April 26 cases and 2 deaths; in May 1 case and no deaths, showing apparently that the epidemic had expended itself by the close of the month of April, and that there were in the neighborhood of 1200 cases and nearly 100 deaths, as the result of flushing the sewers at Crookston, sixty miles up stream from Grand Forks. (William's testimony, Vol. 3, pages 2455 and 2456.)

The evidence of Drs. Willis, C. B. Stockwell, Oliver Stewart, E. J. Haynes, Vol. 3, pp. 2690, 2715, 2720, 2745, together with the testimony of F. R. Rogers, Vol. 3, page 2730, is to the effect that prior to the typhoid epidemic at Detroit it was investigated by Mr. Williams, who found a variable number of typhoid fever deaths, and a larger number of cases of typhoid occurred in the city of Port Huron, and that this typhoid death rate was continuous from year to year for at least thirty years prior to 1892. Black river is shown to pass directly through the town

of Port Huron. The matter which had sedimented in front of the city became so extensive that it was necessary for the government of the United States to dredge in front of the city in order to admit navigation at the mouth of Black river. This is described by Mr. Williams as the immediate cause of the typhoid epidemic at Detroit following some weeks after the dredging. The territory surrounding Port Huron and Detroit was thoroughly investigated for the purpose of determining whether or not the typhoid epidemic had taken place on the watershed above the city, and every available means was employed to ascertain the true source of the infection, the final and ultimate conclusion being that it could be attributed to no cause other than the dredging of the river at Port Huron.

WASHINGTON EPIDEMIC.

It is a well known fact that the polluting and infectious matter contained in the Potomac river at Washington was derived largely from Cumberland, Maryland, a city situated upon the Cumberland river, 175 miles above Washington. In January, February and March of 1890, Cumberland suffered a typhoid epidemic which became very extensive; the result of this was that within a short time typhoid fever appeared in Washington City. In January there were 18 deaths from typhoid at Cumberland, in February 27, in March 29, in April 8 and in May 5. The effect of this was that the epidemic became current in March in Washington, the total deaths from typhoid being 19, and this epidemic extended through to August, the number of deaths being as follows: March 19, April 11, May 13, June 33, July 36, August 28. This epidemic is particularly interesting and has been repeatedly referred to in public meetings, and in hearings before Congressional and other committees at Washington. It is a very instructive example of the transmission of typhoid fever through polluted streams, for the reason that Cumberland is about 175 miles from Washington by river, the river being of such a character as to offer a good example of a stream not very swift or not very slow, having occasional stages of slack water which are succeeded by steeper portions, therefore

offering a good opportunity for the so-called self-purification. Washington has no doubt an excessive death rate from typhoid fever. It has been repeatedly attributed in part by competent experts to the use of Potomac river water for drinking purposes. During March, 1890, through to August of the same year, the cases of typhoid reached extraordinary proportions, so much so that if the typhoid deaths of these months are compared with the average typhoid mortality for the five years previous and the five years afterwards it appears to have amounted to about 100 per cent; that is to say, that in addition to the ordinary typhoid mortality of Washington, there was apparently owing to this epidemic in Cumberland a further excess of about 100 per cent. So clear was this connection regarded by local authorities and by experts that when a case of Asiatic cholera was reported to have appeared in Cumberland, Maryland, in 1894, great uneasiness was felt by the experts in Washington, though fortunately the case proved to be something else than Asiatic cholera.

The question naturally following is, how long does it take water to flow from Cumberland to Washington, and this has been variously estimated, and has been given by Capt. Gaillard of the U. S. Engineers, in Senate document No. 94, 55th Congress, second session, as from four to seven days from Cumberland to the intake.

It is also true in connection with the epidemic in Washington in 1890, following the epidemic in Cumberland, Maryland, in the same year, that the excess of deaths from typhoid fever in Washington is not clearly marked until about two months after the outbreak in Cumberland. That is to say, while there were 18 deaths in Cumberland in January, 1890, no marked excess appears in Washington until March. Furthermore, while the epidemic in Cumberland ended in May, that in Washington was continued vigorously during July and even to some extent in August. Whether this delay in the instance of deaths in Washington is or is not due to the temporary deposit of germs in the bed of the stream to which they were afterwards returned from the flowing water and delivered in Washington it is impossible to say positively, but it is difficult to resist the feeling that this may have been the case. It is certainly a remarkable

and interesting fact. We know, to be sure, that persons who have had typhoid fever continue, even after recovering, often for considerable periods, to discharge germs from the body, and it may have been that the tardy appearance in Washington was due to this cause. It will also be noted in this connection that after allowing time for the passage of the germs from Cumberland to Washington and the period of incubation and time for the death of the patient that there is a remarkable concurrence between the two epidemics, the one following properly after the other. (Sedgwick's testimony, Vol. 3, 2759-60-1-2-3. See also testimony of Dr. W. W. Wiley and Dr. W. C. Woodward, Vol. 3, pages 2857 and 2878.)

6.

BACILLI COLI COMMUNIS.

Where the bacillus coli communis is present in running water in such numbers that its presence can readily be determined by analyzing one cubic centimeter or less of water, it is an indication of contamination by foecal matter, and therefore is a valuable test in connection with the chemical analysis of water for the purpose of determining its sanitary qualities. (Whipple, cross examination, Vol. 3, pages 2375-6-7.)

Bacilli coli communis, as a general proposition, is considered non-pathogenic. It becomes pathogenic, however, when injected under the skin or when it gets into the blood stream or lymphatic stream from the intestinal canal. It is one of the most active causes of appendicitis.

(Dr. Ravold's testimony, printed record, Volume 1, page 801.)

An examination of the fish contained in the waters of the Missouri, Mississippi and Illinois rivers discloses the fact that the bacilli coli communis is contained in fish in the Illinois river in large quantities, and to some extent in the fish in the water of the Mississippi river, but was not found in the fish in the water of the Missouri river. It is not, however, a natural habitat of fish, but eighty per cent. of the fish examined from the Illinois river were found to contain it.

(Dr. Ravold's testimony, printed record, Volume 1, pages 25 and 26.)

There is no record of it ever having been found in fish before this investigation.

(Printed record, Volume 1, page 68.)

The samples of water taken during the months of May, June and July, 1900, show that bacilli coli communis were found in the water of the drainage canal in 87 per cent. of the samples analyzed, and during August, September and October, 1900, 100 per cent. of the samples contained coli.

(Dr. Ravold's testimony, printed record, Volume 1, page 98.)

During the second period, or during the year 1900, it was found to be contained in 99 per cent. of the samples of water analyzed from the drainage canal, and during the third period at Joliet it was found to exist in 79.2 per cent. of the samples examined. At Rubey Street Station, Joliet, from September 26th to November 25th, 1901, coli was found to be present in 83 per cent. of the samples examined. At Brandons Bridge, Joliet, it was found to be contained in 79 per cent. of the samples examined.

(Dr. Ravold's testimony, printed record, Volume 1, pages 231-233.)

During the month of October, 1901, coli was found in 87.1 per cent of the samples of water taken from the Illinois river three miles above Peoria, and in November, 1901, of the water taken from the river three miles above Peoria it was found in 79.1 per cent of the samples analyzed.

(Dr. Ravold's testimony, printed record, Volume 1, pages 232-233.)

At Grafton, at the mouth of the Illinois river, during the month of October and November, 1901, it was found in 53.6 per cent of the samples examined, and during the same month it was found in but 47 per cent of the samples examined from the Mississippi river above Grafton, and above the mouth of the Illinois. There is much less coli in the waters of the Missouri river than in that of the Mississippi and the Illinois rivers, as shown by the testimony of Dr. Ravold, printed record, volume 1, pages 252-259, inclusive.

(Printed record, Volume 1, page 890.)

7.

BACTERIAL CONTENTS OF ILLINOIS, MISSISSIPPI AND MISSOURI RIVERS COMPARED, SHOWING THE EFFECT ON THE LAKE MICHIGAN WATER AND THE SEWERAGE OF CHICAGO UPON THE WATERS OF THE ILLINOIS RIVER AND OF THE MISSISSIPPI RIVER BELOW THE MOUTH OF THE ILLLINOIS RIVER FROM A BACTERIOLOGICAL STANDPOINT.

Three periods of scientific bacterial determinations of the waters of the Mississippi, Missouri and Illinois rivers were made for the purpose, if possible, of determining the effect the water of the Illinois river had upon the St. Louis water supply. Samples of water were collected at various points on the respective rivers, which were put to chemical and bacteriological tests.

During the first period, to-wit, from August 23rd, 1899, to January 23rd, 1900, samples of water were collected at the following named places on the rivers in question:

Mississippi river,

Chain of Rocks, 300 feet from the Missouri shore.

Chain of Rocks, 300 feet from the Illinois shore.

Chain of Rocks, Intake Tower, about 1,500 feet from the Missouri shore.

St. Louis Distributing Well.

Madison Landing, immediately below the mouth of the Missouri river.

Missouri river at its mouth.

Mississippi river below Alton.

Mississippi river near Clifton Terrace above Alton.

Mississippi river immediately below Grafton.

Illinois river above Grafton.

Mississippi river above Grafton.

(Printed record, Volume 1, page 641.)

During the second period, which began on the 23rd day of

January and ended on the 23rd day of November, 1901, samples of water were collected from

Lake Michigan,

The Illinois and Michigan Canal at Lockport,

Chicago Drainage Canal above Bear Trap Dam,

Des Plaines river at Joliet.

Des Plaines river above the entrance of the Chicago Drainage Canal,

Illinois river three miles above Grafton,

Illinois river at Wesley, Illinois, immediately below,

Illinois river three miles above Pekin bridge,

Mississippi river two miles above Grafton,

Mississippi river at Hartford below Alton,

The Missouri river at Fort Bellefontaine,

Mississippi river at Chain of Rocks, three hundred feet from Missouri shore,

Mississippi river, Chain of Rocks, three hundred feet from Illinois shore,

Mississippi river, Chain of Rocks, Intake Tower, 1,500 feet from Missouri shore,

St. Louis Water Works out-let chamber,

St. Louis water tap at City Chemist's office in the old city hall.

During the third period, from October 1st, 1901, to November 30th, 1901, samples of water were taken during this period from

Illinois and Michigan Canal at Bridgeport,

Chicago Drainage Canal at Bridgeport,

Chicago Drainage Canal at Lockport,

Chicago Drainage Canal immediately above Bear Trap Dam,

Illinois and Michigan Canal at Lockport,

Des Plaines river above Bear Trap Dam,

Des Plaines river above Ninth Street Tower at Joliet,

Des Plaines river at Rubey Street Station, Joliet,

Des Plaines river at Brandon's Bridge, Joliet,

Illinois river at LaSalle, Illinois,

Illinois river three miles above railway bridge at Peoria,

Illinois river at Pekin,

Illinois river at King[illegible] eight miles below Pekin,
Illinois river at Grafton,
Mississippi river at Grafton,
Mississippi river at Alton,
Mississippi river at Hartford below Alton.
Mississippi river, Chain of Rocks, mid-stream,
Mississippi river, Chain of Rocks, three hundred feet from Missouri shore,
Mississippi river, Chain of Rocks, three hundred feet from Illinois shore.
Missouri river at Fort Bellefontaine,
St. Louis Water Works, out-let chamber,
St. Louis Water Works tap in office of City Chemist at City Hall.
(Printed record, Volume 1, page 665.)

During these periods, samples of water were collected daily and immediately analyzed for the purpose of obtaining their chemical and bacterial contents.

In addition to this, cross-sections of the samples of the waters of the Mississippi, Illinois and Missouri rivers were taken at the following respective points:

Mississippi river, Chain of Rocks,
Mississippi river at Alton,
Mississippi river at Hartford,
Missouri river at Fort Bellefontaine,
Illinois river at Pekin.
Illinois river at Kingston,
Illinois river at Peoria,
Des Plaines river at Joliet.

These cross-sections were taken by dividing the rivers into ten or twelve equal portions, and taking samples of water from the respective points.

(Printed record, Volume 1, pages 57-58, 64, 111-114, 666-667.)

During the first period of examination in the year 1893, the average bacteria per C. C. in the water of the Mississippi river at the up-take at the Chain of Rocks was 489.

(Dr. Ravold's testimony, printed record, Volume 1, pages 80-81.)

During the same period, 1899, at Wheeler's Ferry on the Illinois river, three miles above its mouth, the average of 162 bacteria per C. C.

Illinois river, five miles above its mouth, 160 bacteria per C. C.

Mississippi river at Grafton above the mouth of the Illinois river, 190 bacteria per C. C.

Mississippi river six miles above Alton, 276 bacteria per C. C.

Mississippi river, Chain of Rocks, 160 bacteria per C. C.

Missouri river at its mouth 1,070 bacteria per C. C.

During the second period of investigation the average daily count at Bear Trap Dam was 1,825,000 bacteria per C. C., 200 daily tests being made. While the average daily count of bacteria for eight days immediately following opening of the canal was 20,663,000 bacteria per C. C.

(Dr. Ravold's testimony, printed record, Volume 1, pages 100-106.)

Lake Michigan disclosed 37,700 bacteria per C. C., with coli communis present in 66—2-3 of the samples examined.

At the Four Mile Crib during the second period of examination in 1900 the bacterial contents of the water of Lake Michigan was 47,500 bacteria per C. C.

At 68th Street Crib, Lake Michigan, the bacterial contents of the water disclosed 82,000 bacteria per C. C.

(Dr. Ravold's testimony, printed record, Volume 1, pages 94-96.)

For the week of January 30th, 1900, the bacterial contents of the water of the Illinois river at Grafton, as shown by the investigation made by Dr. Ravold, disclosed 116,000 bacteria per C. C.

For the week of February 6th, 1900, 109,000 bacteria per C. C.

For the week of February 13th, 1900, 257,000 bacteria per C. C.

For the week of February 20th, 1900, 221,000 bacteria per C. C.

For the week of February 27th, 1900, 223,100 bacteria per C. C.

For the week of March 6th, 1900, 267,700 bacteria per C. C.
For the week of March 13th, 1900, 239,000 bacteria per C. C.
For the week of March 20th, 1900, 204,000 bacteria per C. C.
For the week of March 27th, 1900, 151,000 bacteria per C. C.
(Printed record, Volume 1, pages 353-354.)

Dr. Ravold's bacterial examination of the water of Lake Michigan during the second period discloses the following results:

Four Mile Crib, one of the intakes of the water supply of Chicago, Lake Michigan, 1,600 bacteria per C. C., with coli communis present.

The Carter Harrison Crib, located about ten miles from Chicago, Lake Michigan, on July 30th, 1900, disclosed 12,300 bacteria per C. C., with the coli communis present.

The samples of water being taken ten feet below the surface. The crib not being ten miles out in the lake, but the samples of water were taken that distance in a direct line with the crib and the city.

(Dr. Ravold's testimony, printed record, Volume 1, page 94.)

On August 9th, 1900, the samples of water at a point ten miles in Lake Michigan, disclosed 16,300 bacteria per C. C., with coli communis present.

During the second period the bacterial examination of the water at Carter Harrison Crib, in Lake Michigan, disclosed 16,850 bacteria per C. C., with coli communis present.

At Lake View Crib, Chicago, the determination during this period resulted in a disclose of 4,650 bacteria per C. C.

At Two Mile Crib during the second period of the investigation the bacterial contents of the water was 308,466 bacteria per

C. C., with coli communis present in 66—2-3 of the samples examined.

The effect of the sewerage of Chicago upon the water of the Mississippi river is shown by the bacterial contents of the water at Hartford, seven miles below Alton and one mile above the union of the Missouri and Mississippi rivers, during the second period of examination in the months of January, February and March, 1900, is as follows:

For week ending January 30th, 1900, 87,500 bacteria per C. C.

For week ending February 6th, 1900, 147,000 bacteria per C. C.

For week ending February 13th, 1900, 160,500 bacteria per C. C.

For week ending February 20th, 1900, 233,500 bacteria per C. C.

For week ending February 27th, 1900, 266,900 bacteria per C. C.

For week ending March 6th, 1900, 193,000 bacteria per C. C.

For week ending March 13th, 1900, 209,000 bacteria per C. C.

For week ending March 20th, 1900, 320,500 bacteria per C. C.

For week ending March 27, 1900, 227,600 bacteria per C. C.

(Dr. Ravold's testimony, printed record, Volume 1, page 358.)

It will be well to remember in this connection that the drainage canal was opened on the 17th day of January, 1900.

During the same period, to-wit, the second period of investigation, the bacterial determination of the waters at Intake Tower, Chain of Rocks, about one hundred feet in front of the tower, the weekly result of the investigation is as follows:

For the week ending February 6th, 1900, 75,000 bacteria per C. C.

For the week ending February 13th, 1900, 133,500 bacteria per C. C.

For the week ending February 20th, 1900, 112,500 bacteria per C. C.

For the week ending February 27th, 1900, 53,000 bacteria per C. C.

For the week ending March 6th, 1900, 177,000 bacteria per C. C.

For the week ending March 13th, 1900, 200,000 bacteria per C. C.

For the week ending March 20th, 1900, 200,000 bacteria per C. C.

For the week ending March 27th, 1900, 118,000 bacteria per C. C.

The effect of the sewerage of Chicago upon the water supply of St. Louis is shown by the following bacterial results obtained from samples taken at the outlet chambers at the reservoir of the St. Louis water supply at Chain of Rocks. These samples were taken from the water which comes from the reservoir into the conduit which carries the water over to Baden leading into the conduit at Bissell's Point.

For the week ending February 6th, 31,000 bacteria per C. C.

For the week ending February 13th, 42,000 bacteria per C. C.

For the week ending February 20th, 106,500 bacteria per C. C.

For the week ending February 27th, 53,000 bacteria per C. C.

For the week ending March 6th, 70,000 bacteria per C. C.

For the week ending March 13th, 200,000 bacteria per C. C.

For the week ending March 20th, 200,000 bacteria per C. C.

For the week ending March 27th, 76,500 bacteria per C. C.

(Dr. Ravold's testimony, printed record, Volume 1, pages 355-363.)

In this connection it might be well to show from the record the comparative effect of the opening of the drainage canal on January 17th, 1900, upon the waters of the Mississippi river and immediately thereafter.

This is shown by the weekly averages of the bacterial counts in the investigation made of the waters of the respective rivers before and after the opening of the canal.

For week beginning January 30th, or thirteen days after the opening of the canal, the average number of bacteria found in the Illinois river at Grafton was 189,500 bacterial per C. C.

The Mississippi river above Grafton, 46,000 bacteria per C. C.

Mississippi river at Alton, 115,000 bacteria per C. C.

Illinois shore, Chain of Rocks, 76,000 bacteria per C. C.

For the week beginning February 6th,

Illinois river, 257,600 bacteria per C. C.

Mississippi river above Grafton, 43,000 bacteria per C. C.

Mississippi river at Alton, 100,000 bacteria per C. C.

Missouri river at Fort Bellefontaine, 63,000 bacteria per C. C.

Mississippi river at Missouri shore, Chain of Rocks, 58,000 bacteria per C. C.

Mississippi river, Illinois shore, Chain of Rocks, 106,000 bacteria per C. C.

Mississippi river, Intake Tower, 75,000 bacteria per C. C.

For the week beginning February 20th,

Illinois river at Grafton, 221,800 bacteria per C. C.

Mississippi river at Grafton, 195,000 bacteria per C. C.

Missouri river at Fort Bellefontaine, 70,000 bacteria per C. C.

Mississippi river, Chain of Rocks, 300 feet from Missouri shore, 77,000 bacteria per C. C.

Mississippi river, 300 feet from Illinois shore, 192,000 bacteria per C. C.

Mississippi river at Intake, Chain of Rocks, 112,000 bacteria per C. C.

For the week beginning February 27th,

Illinois river at Grafton, 223,100 bacteria per C. C.

Mississippi river above Grafton, 55,000 bacteria per C. C.

Mississippi river at Alton, 156,500 bacteria per C. C.

Missouri river at Fort Bellefontaine, 63,000 bacteria per C. C.

Mississippi river, Missouri shore, Chain of Rocks, 50,500 bacteria per C. C.

Mississippi river, Chain of Rocks, Illinois shore, 77,000 bacteria per C. C.

Mississippi river, Intake Tower, 53,300 bacteria per C. C.

(Dr. Ravold's testimony, printed record, Volume 1, pages 366-367.)

For further showing as to the effect of the sewerage of Chicago upon the waters of the Mississippi river at the Chain of Rocks, we call attention to the following comparison. These comparisons also show a complete mixing of the water of the three rivers, Mississippi, Missouri and Illinois, at the Intake Tower, St. Louis. This is obtained by making a comparison of the bacterial count of the water of the Mississippi river above Grafton, the Illinois river at Grafton and the Missouri river at Fort Bellefontaine, and the Mississippi river, Chain of Rocks, Intake Tower.

For week beginning February 6th, 1900,

Illinois river at Grafton, 109,000 bacteria per C. C.

Mississippi river above Grafton, 46,000 bacteria per C. C.

Mississippi river at Alton, 400,500 bacteria per C. C.

Mississippi river at Hartford, 106,500 bacteria per C. C.

Mississippi river at Intake Tower, St. Louis, 75,000 bacteria per C. C.

Missouri river at Fort Bellefontaine, 62,000 bacteria per C. C.

It will be observed from the foregoing table that the Mississippi river above Grafton contains 63,000 less bacteria per C. C. than the Illinois river at Grafton, and the Mississippi river at Alton contains 54,500 more bacteria per C. C. than it did above Grafton, and that the Mississippi river at the Intake, St. Louis Water Works, contains 29,000 more bacteria per C. C. than it did above Grafton, and that the Missouri river at Fort Bellefontaine contains 46,000 less bacteria per C. C. than the Illinois river at Grafton, and 12,000 less than the Mississippi river at the Intake.

For the week beginning February 13th,

Illinois river at Grafton, 257,600 bacteria per C. C.

Mississippi river above Grafton, 161,000 bacteria per C. C.

Mississippi river at Hartford, 233,100 bacteria per C. C.

Mississippi river at Intake, Chain of Rocks, 133,500 bacteria per C. C.

Missouri river at Fort Bellefontaine, 52,000 bacteria per C. C.

It will be observed from the foregoing table that the Mississippi river above Grafton contained 96,000 less bacteria per C. C. than the Illinois river at Grafton, and the Mississippi river at Hartford contained 92,100 more bacteria per C. C. than the same river did above Grafton, and that the Mississippi river at the Intake, Chain of Rocks, St. Louis Water Works, contained 81,500 more than the Missouri river did at Fort Bellefontaine, and the Missouri river at Fort Bellefontaine contained 81,500 less bacteria per C. C. than the Mississippi river at Intake.

For the week beginning February 20th,

Illinois river at Grafton 221,800 bacteria per C. C.

Mississippi river above Grafton, 105,000 bacteria per C. C.

Mississippi river at Intake, 112,000 bacteria per C. C.

Missouri river at Fort Bellefontaine, 69,500 bacteria per C. C.

It will be observed from the foregoing table that the Mississippi river above Grafton contained 116,800 less bacteria than the Illinois river did at its mouth, and the Mississippi river at the Intake contained 7,000 more bacteria than it did at Grafton, while the Missouri river at Fort Bellefontaine contained 152,300 less than the Illinois river at Grafton, and 42,500 less than the Mississippi river at the Intake of the St. Louis water supply.

For the week beginning February 27th,

Illinois river at Grafton contains 223,100 bacteria per C. C.

Mississippi river above Grafton, 55,000 bacteria per C. C.

Mississippi river at Hartford, 142,000 bacteria per C. C.

Mississippi river at the Intake, St. Louis water supply, 77,000 bacteria per C. C.

Missouri river at Fort Bellefontaine, 63,000 bacteria per C. C.

It will be observed from the foregoing table that the Mississippi river at Grafton contained 168,000 less bacteria than the Illinois river at Grafton, and the Mississippi river at the Intake contains 22,000 more than it did at Grafton, and the Missouri river at Fort Bellefontaine contained 14,000 less bacteria than the Mississippi river at the Intake, and 160,000 less than the Illinois river at Grafton.

(Dr. Ravold's testimony, printed record, Volume 1, pages 378-380, inc.)

In connection with the foregoing, we call attention to complainant's exhibit No. 2 and the explanation of it given by Dr. Ravold in Volume 1 of the printed record at pages 382 to 383:

"On January 23, at the Illinois shore directly across from the Intake, we find the number of bacteria reaches 240,000. The number in the Missouri river is 105,000. The number at the Intake between these points 150,000. On January 30th, we find the number of bacteria in the Mississippi river 150,000; the number in the Intake 135,000, and the number on the Missouri shore of the Mississippi river 75,000. While we have the Intake standing between these two numbers, not quite mid-way, but showing more Mississippi river water coming into the Intake containing 135,000 bacteria per C. C. These figures would indicate that the water at the Intake is more Mississippi river than the Missouri river and so we go throughout the map."

This exhibit shows clearly a general mixing of the water of the Mississippi before the Intake at the Chain of Rocks is reached.

Samples of water were collected from the Mississippi river at Intake Tower, St. Louis Water Works, between the 1st and the 15th of February, 1900, or a few days after the opening of the drainage canal.

Samples were also collected from the Illinois river at Grafton, Peoria and from the Mississippi river above Alton, Hartford on the Illinois shore, and Missouri river at Fort Bellefontaine.

Samples of water collected from Peoria were almost black, entirely different from the ordinary condition of the water. The

water at Grafton was as dark as that at Peoria, and the water flowing down from Alton and Hartford was black [illegible] exhibited a mixture with the Mississippi river as it came in at Grafton, not being quite so dark. The Mississippi river was very clear, remarkably so.

The samples coming from the Missouri river at Fort Bellefontaine was as clear as the water of that river generally obtains.

The water on the Missouri shore, to the naked eye, was about the color of that in the Missouri river, but at the Intake there was a distinct mixture of the waters of the Illinois river with the Missouri river, as shown by a comparison of the samples from the respective points. The bacteriological results at this time exhibited a remarkable condition.

In the samples of the water from the Illinois at Grafton, the number of bacteria were very high, while there was a low number in the Mississippi river above Grafton, and a still lower number in the Missouri river at Fort Bellefontaine.

The bacterial characteristic of the water also presented a complete mixing of the Illinois with the Mississippi river above the Missouri, and the Mississippi above the Missouri shows a distinct mixture.

(Printed record, Volume 1, pages 835-836.)

The defendants carried on a series of bacteriological and chemical analyses of the waters of Lake Michigan. These experiments were conducted by different analysts to-wit, Prof. Palmer, Prof. Long, Doctor Bisbee and Prof. Jordan. An examination of the tables discloses a very great difference in the analytical results obtained from samples of water collected at the same points at the same time, but examined by the different experts. These differences run from 5 to100 per cent, and show clearly that little or no reliance can be placed upon the accuracy of the determinations made.

Especial reference is made to table No. 20 of the series of tables, 1 to 80, inclusive, made by Prof. Palmer, and table 178, of the evidence introduced by defendants and known as Defendants' Tables of Streams Examined, 1 to 196, inclusive. and said table No. 178 constituted a part of the testimony of Mr. Bisbee.

It will be found upon comparison that these tables, during the month of September, 1899, and the samples of water collected by the same doctor at the same point, as companion samples, one of which was shipped to Prof. Palmer and the other to Mr. Bisbee, all of which were analyzed by Prof. Palmer, to-wit, September 7th, 14th, 21st and 28th, differed materially. Mr. Bisbee analyzed three of said samples, to-wit, those collected September 7th, 14th, and 21st, the samples being collected on the 6th, 13th, 20th and 27th days of September, 1899. Upon the determinations made by Prof. Palmer it was found that upon September 7th the contents disclosed 1.0 of organic nitrogen, in the sample analyzed on the 14th of September .84 of organic nitrogen, in the sample analyzed on the 27th of September 1.0 of organic nitrogen, and in the sample analyzed on the 28th of September .82 of organic nitrogen, while Mr. Bisbee, in his analyses, found that the samples analyzed by him were as follows:

September 7th, organic nitrogen	.60
September 14, organic nitrogen	1.04
September 21st, organic nitrogen	.76

No analysis was made of the samples collected on the 27th of September. The samples above referred to were taken from the Illinois river at Kampsville. It will be observed from the comparison of these analyses that a variation is shown of 18.8 per cent, counting those made by Prof. Palmer at 100.

Referring to the total solids in suspension as determined by Prof. Palmer and compared with a like determination made by Prof. Bisbee on the 8th of November, we find a difference in suspended matter of 90 per cent. The variation in nitrates is 48 per cent, in free ammonia 3.9 per cent, albuminoid ammonia 28 per cent. What is true with reference to the questions above referred to may be said of the entire series of observations made by the respective analysts. (See Palmer's testimony, Vol. 6, pp. 5665, 5673, inclusive.)

An examination of the testimony of Prof. Jordan will also disclose that there is a wide range of difference existing between the results obtained by him, Prof. Jordan, and Prof. Palmer. While it is true in all chemical analyses of water there is a per-

centage of variation in the analysis, attributed to inaccuracy in the determination, this percentage of inaccuracy is stated by Prof. Palmer to be about 10 per cent, while it is said by Prof. Jordan to be about 2 per cent, yet the variations existing between the determinations made by the respective witnesses range from 5 to 100 per cent. (See Jordan's testimony, Vol. 7, pp. 6367-8-9-70.)

8.

BACTERIAL CONDITION IN THE ILLINOIS RIVER HAS GROWN MORE DANGEROUS SINCE THE CANAL WAS OPENED.

According to the bacterial analyses of Prof. Jordan, the bacterial increase in the Illinois river since the opening of the canal as compared with conditions prior thereto, is as follows:

Averyville, above Peoria, increase in number of bacteria per cubic centimetre, 48,200.

Kampsville, 27,000.

Grafton, 11,000.

(See Jordan's testimony, Vol. 6, p. 5967.)

It may be well to state here from the record that various pathogenic bacteria were found in the waters of the drainage canal and the Illinois river at Morris, Henry and Havanna. The character of pathogenic bacteria so found were as follows:

Seven samples of water collected from the drainage canal disclosed the following results:

Bacteria coli communis	6
Bacteria lactis aerodenes	4
Bacteria cuteretides	2
Proteus vulgaris	6
Bacteria byocanendus	2

At Morris the samples were collected with the following results:

Bacilli coli communis,
Proteus vulgaris,
Proteus mirabilis,
Bacteria tetana, or tetanus.

At Henry five samples were collected with the following results:

Bacteria coli communis,
Proteus vulgaris,
Bacteria tetana, or tetanus,
Staphyloculus.

At Havanna twelve samples were collected with the following results:

Bacteria coli communis,
Bacteria lactis aerodenes,
Proteus mirabilis,
Bacteria anthracis, or anthrax.

(Zeit's testimony, Vol. 5, p. 4406.)

The above determinations were made in the year 1900, subsequent to the opening of the drainage canal.

These discoveries were obtained from a small number of samples collected where the water was examined for the purpose of determining the character of the bacteria found, regardless of the quantity, and it is remarkable to note that so many pathogenic bacteria should be found in the few samples determined. More striking is this when you take into consideraiton the fact that bacteriologists have been using every possible means to discover some way by which pathogenic bacteria might be readily determined in the water. So far as typhoid fever germs are concerned, it is practically a matter of waste of time to undertake such determinations. According to Prof. Zeit, the determinations are so intricate and delicate that bacteriologists have abandoned the idea of making such discovery. So that so far as bacteriology is concerned the fact that pathogenic bacteria are not found in water constitutes no reason to conclude that such bacteria are not contained in it. The science of chemistry also fails to disclose the true condition of the water from the scientific sanitary standpoint. Water may be pronounced safe by chemists and yet contain disease producing organisms, so that so far as the science of chemistry and bacteriology alone are concerned, no accurate conclusions can be arrived at, and no correct determinations made which will enable

one to determine accurately the sanitary condition of the water. (Long's cross-examination, Vol. 5, p. 4333; Zeit's cross-examination, Vol. 5, p. 4427; Palmer's cross-examination, Vol. 6, p. 5653.)

Chemistry, however, does disclose a certain residue in water, but does not disclose the character of such residue. (Palmer's testimony, Vol. 6, pp. 5655-6-8.)

9.

CHEMICAL CONSTITUENTS OF THE WATER SHOWING INCREASE POLLUTION OF THE ILLINOIS RIVER SINCE THE OPENING OF THE CHICAGO DRAINAGE CANAL.

In the examination of water supplies for the purpose of determining their fitness for domestic use, the science of chemistry has heretofore been applied as an aid towards such determination. Chemists are frequently called upon by individuals or water companies to pass judgment upon the character of water for drinking and domestic purposes. Before such judgment is expressed it becomes necessary for them to make an analysis of the water with a view of determining as near as possible the relative proportions of chemical constituents contained therein, which from long experience and study are looked upon as evidence of sewage pollution. These constituents found in the water are, of course, not sufficient to enable the chemist to express an accurate opinion, unless he is acquainted somewhat with the local history of the water and physical conditions affecting its source, its flow and the place of its retention.

In this connection it will be well to bear in mind the extent of the area of the drainage basis of the respective rivers, the Missouri, the Mississippi above Grafton and the Illinois. The watershed of the Missouri river consists of a much greater area of territory, and is less thickly populated than either the Mississippi or the Illinois rivers. While the Mississippi river watershed is more extensive than that of the Illinois river, and the population situated thereon much less than that of the Illinois, while the Illinois

watershed, exclusive of the city of Chicago and the Sanitary District of Chicago, is much less in area and more thickly populated than either of the other two. By adding to this the population of the city of Chicago and of the Sanitary District, amounting to about 2,000,000, more than doubles the sewage discharged annually into the Illinois river. So that from the surrounding facts it is natural to believe and suspect that the waters of the Illinois river are more highly contaminated with sewage than either of the three rivers, and more particularly is this true when we take into consideration the fact that the volume of water passing down the Illinois is much less than that found in either the Mississippi or the Missouri; and as to population per square mile of territory it is much greater. These facts carried along with the results obtained from the chemical analysis of the respective waters are sufficient when properly considered to enable one to determine the relative values of the respective waters.

In making the determination in the analysis of water, it became the purpose of the chemists to ascertain the following chemical constituents:

First—Total solid matter.
Second—The amount of free ammonia.
Third—The amount of albuminoid ammonia.
Fourth—Total ammonia.
Fifth—The oxygen consuming the properties of the water.
Sixth—The nitrogen present as nitrates.
Seventh—The nitrogen present as nitrites.
Eighth—The chlorine.
(Keiser's testimony, printed record, Volume 1, page 975.)

It might be well here to refer specifically to Professor Keiser's statement as to those chemical constituents classed as nitrogen and usually coming from decomposed nitrogenous matter. The chemist looks upon nitrogen as an element that is characteristic of living things. Nitrogen goes through a cycle of changes in living matter and the presence of nitrogen compounds in water shows that the water has become contaminated with matter of vegetable or animal origin; so that the chemist

attaches very great importance to the detection of nitrogen in its various forms in natural water. A pure water is free from all nitrogen compounds, but such water is never found in nature. All natural waters contain varying amounts of nitrogen in some form. The chemist looks for nitrogen in four forms: First, as free ammonia; second, as albuminoid ammonia; third, as nitrites, and, lastly, as nitrates. It might be said that the cycle of changes through which nitrogen goes is something like this: Vegetable matter requires nitrates for its growth and development. The roots of plants take up nitrates from the soil or from water, and the plant builds up complex nitrogenous compounds or albuminoids, such substances as gluten of wheat and similar albuminous substances. These albuminous substances are the foods of animals, and animals live upon these albuminous substances. And in their life processes they break down the complex nitrogenous compounds that plants have built up, to simpler compounds which are not albuminoids, and these products that are eliminated from animal bodies find their way into water and are broken down still further by still lower forms of life, by bacteria. They break down these products eliminated from animal bodies, into still simpler forms of nitrogenous compounds, namely, ammonia and nitrites, and by still further action of bacteria the ammonia and nitrites are brought back again into the nitrates. And then it is in the condition for plants to again absorb it and take it and build up the complex nitrogenous compounds which serve as food for animals. So that nitrogen is going through a cycle of changes. It is being built up into complex compounds, and animals live upon these substances and break them down partially, and then they are finally reduced to the nitrates by means of organisms in the soil and water. This is what we call the nitrogen cycle.

(Prof. Keiser's testimony, printed record, Volume 1, pages 975-976.)

Chemists attach great importance to the detection of nitrogen compounds in water. When there found it is evident that there is nitrogenous organic matter undergoing putrefaction. It is searched for in the form of free ammonia, albuminoid, ammonia, nitrites and nitrates.

(Prof. Keiser's testimony, printed record, Volume 1, page 976.)

During the entire chemical investigation of the waters in question, Professor Keiser used the method recommended by the American Society for the Advancement of Science, which is regarded as the standard method, and is generally used at the present.

(Prof. Keiser's testimony, printed record, Volume 1, page 908.)

Commencing on the 24th day of January, 1900, and ending on the 11th day of October, 1900, samples of water were daily collected for chemical observations and placed in the hands of Professor Keiser, as well as other chemists who testified in the case, for chemical analysis. These samples were collected from the following places:

In the Mississippi, Missouri and Illinois rivers:

1st. The reservoir at the Chain of Rocks.
2nd. The Wet Well, Chain of Rocks.
3rd. The Intake Tower Waterworks, Chain of Rocks.
4th. TheMississippi river at Chain of Rocks, 300 feet from Missouri shore.
5th. The Mississippi river, Chain of Rocks, 300 feet from Illinois shore.
6th. In Missouri river at Fort Bellefontaine.
7th. The Mississippi river at Hartford.
8th. The Mississippi river at Alton.
9th. The Mississippi river three miles above Grafton.
10th. In the Illinois river three miles above Grafton.
11th. The Illinois river two miles above Peoria near Averyville.
12th. The Des Plaines and Chicago Drainage Canal at Lockport and Joliet.

Also in running water in the chemical laboratory of Washington University and the City Chemist's office in the old City Hall, St. Louis; drawn from the tap.

(Prof. Keiser's testimony, printed record, Volume 1, page 981.)

The presence of nitrites and free ammonia, together with chlorine, are regarded of chief importance, for the reason that the presence of measurable quantity of nitrites in drinking water is often regarded as a sure sign of contamination, and a chemist finding a measurable quantity of nitrites in water would condemn it as unsafe for drinking purposes. And so free ammonia, likewise, is of great importance in judging of the sanitary condition of the water for the reason that the first product produced by bacteria in decomposing sewage is free ammonia. A large quantity of free ammonia in sewage is universally found, so that the chemist lays special stress on these two constituents: nitrites and free ammonia.

(Prof. Keiser's testimony, printed record, Volume 1, page 982.)

Free ammonia may be said to be ammonium carbonate, or ammonium chloride existing in the water, and has been formed by the action of bacteria upon nitrogenous organic matter. It is absent from pure water, consequently is looked upon by scientists as an evidence of contamination with nitrogenous organic matter.

(Prof. Keiser's testimony, printed record, Volume 1, page 983.)

The appearance of these constituents in water is proof that the water itself is not able to take care of the contamination or polluted matter discharged into it, which is undergoing putrefaction and decay. Their presence indicate that there is decaying vegetable or animal matter in the water, and for that reason these two chemical constituents constitute a warning to the chemists that the water should be looked upon with suspicion.

(Prof. Keiser's testimony, printed record, Volume 1, page 983.)

The testimony in the case shows that the Illinois and Mississippi river watersheds are free from salt beds, therefore the chlorine found in these waters must have been obtained from artificial discharges or from the sewage of the cities situated thereupon and from the waste of industrial plants. While upon the Missouri river watershed are situated large bodies of salt, and especially is one of its principal tributaries, the Kaw, known to contain large quantities of chlorine coming from the salt beds of Kansas. So that from the chemist's standpoint, if it be discovered that free ammonia, nitrites and chlorine are high, the water will be condemned as sewage polluted. This applies to the Mississippi and the Illinois river water. The chemical analysis of the waters of the Missouri river will show, however, that while the ammonia is high and chlorine high, the nitrites are exceedingly low, therefore indicating that whatever contamination there may be in the waters of the Missouri river it comes from a vegetable and not from an animal origin. The analysis shows further that the chlorine in the upper Mississippi river, together with the free ammonia and nitrites are comparatively low. While in the Illinois river during the periods of investigation the free ammonia, nitrites and chlorine are exceedingly high. This is particularly true with reference to the water in this river subsequent to the opening of the canal. The testimony shows that before the opening of the canal the water was practically in the same condition chemically as that in the Mississippi.

In this connection, we call attention to the weekly and monthly averages of the various chemical constituents heretofore named contained in the respective waters, and ascertained by Professor Keiser in his determinations.

Reservoir water in St. Louis Water Works from January 24th, 1900, to October 11th, 1900:

Nitrites, parts per million.

(Jan. 24th-31st,	.0044)	Before Canal opened.)
Feb. 1-7th,	.0074)	
Feb. 7-14th,	.0080)	Average February, .0133.

Feb. 14-21st,	.0140)	
Feb. 21-28th,	.0240)	
Mar. 1-7th,	.0100)	
Mar. 7-14th,	.0080)	Average March, .0107.
Mar. 14-21st,	.0120)	
Mar. 21-31st,	.0130)	
Apr. 1-7	.0140)	
Apr. 7-14	.0170)	Average April, .0180.
Apr. 14-21	.0260)	
Apr. 21-30	.0140)	
May 1-7	.0097)	
May 7-14	.0046)	Average May, .0055.
May 14-21	.0049)	
May 21-31	.0031)	
June 1-7	.0040)	
June 7-14	.0039)	Average June, .0032.
June 14-21	.0027)	
June 21-30	.0020)	
July 1-7	.0017)	
July 7-14	.0013)	Average July, .0017.
July 14-21	.0021)	
July 21-31	.0017)	
Aug. 1-7	.0004)	
Aug. 7-14	.0018)	Average August, .0021.
Aug. 14-21	.0035)	
Aug. 21-31	.0025)	
Sept. 1-7	.0015)	
Sept. 7-14	.0011)	Average September, .0013.
Sept. 14-21	.0016)	
Sept. 21-30	.0010)	

Oct. 1-10 .0021) Average October, .0021.

(Prof. Keiser's testimony, printed record, Volume 1, pages 984-985.)

Weekly and monthly average of free ammonia in reservoir, St. Louis Water Works:

	Parts per million.	
Jan. 24-31	.1112)	January average .1112.
Feb. 1-7	.2265)	
Feb. 7-14	.2345)	February average .2098.
Feb. 14-21	.1689)	
Feb. 21-28	.2094)	
Mar. 1-7	.1357)	
Mar. 7-14	.1643)	March average .1890.
Mar. 14-21	.1980)	
Mar. 21-31	.2848)	
Apr. 1-7	.2690)	
Apr. 7-14	.2234)	April average .1664.
Apr. 14-21	.1030)	
Apr. 21-30	.0703)	
May 1-7	.0417)	
May 7-14	.0254)	May average .0377.
May 14-21	.0345)	
May 21-31	.0491)	
June 1-7	.0234)	
June 7-14	.0066)	June average .0130.
June 14-21	.0100)	
June 21-30	.0120)	
July 1-7	.0117)	
July 7-14	.0228)	July average .0199.
July 14-21	.0265)	
July 21-31	.0186)	

Aug. 1-7	.0320)	
Aug. 7-14	.0220)	August average .0276.
Aug. 14-21	.0223)	
Aug. 21-31	.0343)	
Sept. 1-7	.0208)	
Sept. 7-14	.0348)	September average .0250.
Sept. 14-21	.0263)	
Sept. 21-30	.0283)	
Oct. 1-10	.0316)	October average .0316.

Prof. Keiser's testimony, printed record, Volume 1, pages 992-993.)

Nitrites contained in water from reservoir of St. Louis Water Works:

	Parts per million.	
Jan. 24-31	.50)	January average .50.
Feb. 1-7	.52)	
Feb. 7-14	.49)	Average for February .59.
Feb. 14-21	.57)	
Feb. 21-28	.78)	
Mar. 1-7	.61)	
Mar. 7-14	.91)	Average for March .77.
Mar. 14-21	.89)	
Mar. 21-31	.67)	
Apr. 1-7	.51)	
Apr. 7-14	.67)	Average for April .56.
Apr. 14-21	.53)	
Apr. 21-30	.54)	
May 1-7	.51)	
May 7-14	.38)	Average for May .39.
May 14-21	.32)	
May 21-31	.35)	

June 1-7	.39)	
June 7-14	.37)	Average for June .41.
June 14-21	.43)	
June 21-30	.43)	
July 1-7	.51)	
July 7-14	49)	Average for July .46.
July 14-21	.34)	
July-21-31	.51)	
Aug. 1-7	.48)	
Aug. 7-14	.27)	Average for August .35.
Aug. 14-21	.22)	
Aug. 21-31	.42)	
Sept. 1-7	.39)	
Sept. 7-14	.36)	Average for September .37.
Sept. 14-21	.36)	
Sept. 21-30	.38)	
Oct. 1-10	.53)	Average for October .53.

(Prof. Keiser's testimony, printed record, Volume 1, pages 999-1000.)

(See also Complainant's exhibit No. 25.)

Albuminoid ammonia in the water of the Reservoir, St. Louis water supply. Table of averages from daily analysis between January 24th and October 10th, 1900:

Jan. 24-31	.214)	Average for January, .214.
Feb. 1-7	.199)	
Feb. 7-14	.285)	Average for February, .271.
Feb. 14-21	.259)	
Feb. 21-28	.344)	
Mar. 1-7	.233)	
Mar. 7-14	.325)	Average for March, .410.
Mar. 14-21	.582)	
Mar. 21-31	.501)	

Apr. 1-7	.264)	
Apr. 7-14	.387)	Average for April, .313.
Apr. 14-21	.248)	
Apr. 21-30	.352)	
May 1-7	.279)	
May 7-14	.285)	Average for May, .261.
May 14-21	.224)	
May 21-31	.257)	
June 1-7	.155)	
June 7-14	.172)	Average for June, .182.
June 14-21	.161)	
June 21-30	.240)	
July 1-7	.219)	
July 7-14	.192)	Average for July, .234.
July 14-21	.249)	
July 21-31	.275)	
Aug. 1-7	.304)	
Aug. 7-14	.233)	Average for August, .257.
Aug. 14-21	.202)	
Aug. 21-31	.289)	
Sept. 1-7	.276)	
Sept. 7-14	.238)	Average for September, .237
Sept. 14-21	.225)	
Sept. 21-30	.210)	
Oct. 1-10	.335)	Average for October, .335.

(Prof Keiser's testimony, printed record, Volume 2, pages 1004-1005.)

We now come to a consideration of the chemical constituents contained in waters of the Mississippi river, 300 feet from the Missouri shore, and 300 feet from the Illinois shore, opposite the Intake Tower at the Chain of Rocks, during the period from

January 24th to October 10th, 1900. During this time samples of water were collected daily and analyzed by Professor Keiser, Dr. Teichmann and others. We here give the table showing the weekly and monthly average of nitrites in parts per million at the above point, as follows:

NITRITES.

Missouri Shore.			Illinois Shore.		
Date.	Parts per million.		Parts per million.		
Jan. 24-31	.0070)	Jan. average, .0070.	.0130)	Jan. average, .0130.	
Feb. 1-7	.0065)		.0214)		
Feb. 7-14	.0183)	Feb. average,	.0000)	Feb. average,	
Feb. 14-21	.0123)	.0144.	.0211)	.0187.	
Feb. 21-28	.0206)		.0136)		
Mar. 1-7	.0140)		.0123)		
Mar. 7-14	.0128)	Mar. average,	.0080)	Mar. average,	
Mar. 14-21	.0183)	.0168.	.0254)	.0164.	
Mar. 21-31	.0223)		.0200)		
Apr. 1-7	.0325)		.0365)		
Apr. 7-14	.0118)	Apr. average,	.0305)	Apr. average,	
Apr. 14-21	.0080)	.0168.	.0288)	.0308.	
Apr. 21-30	.0148)		.0274)		
May 1-7	.0057)		.0157)		
May 7-14	.0028)	May average,	.0134)	May average,	
May 14-21	.0028)	.0035.	.0148)	.0154.	
May 21-31	.0023)		.0178)		
June 1-7	.0028)		.0050)		
June 7-14	.0026)	June average,	.0032)	June average,	
June 14-21	.0028)	.0026.	.0035)	.0050.	
June 21-30	.0024)		.0084)		

Date.	Missouri Shore. Parts per million.		Illinois Shore. Parts per million.	
July 1-7	.0015)		.0041)	
July 7-14	.0017)	July average,	.0043)	July average,
July 14-21	.0010)	.0014.	.0043)	.0041.
July 21-31	.0014)		.0037)	
Aug. 1-7	.0001)		.0037)	
Aug. 7-14	.0015)	Aug. average,	.0077)	Aug. average,
Aug. 14-21	.0014)	.0012.	.0102)	.0063.
Aug. 21-31	.0017)		.0038)	
Sept. 1-7	.0016)		.0070)	
Sept. 7-14	.0003)	Sept. average,	.0071)	Sept. average,
Sept. 14-21	.0004)	.0008.	.0067)	.0068.
Sept. 21-30	.0011)		.0067)	
Oct. 1-10	.0011)	Oct. average,	.0064)	Oct. average,
	)	.0011.	)	.0064.

(Professor Keiser's testimony, printed record, Volume 2, pages 1014-1015.)

FREE AMMONIA.

At the Missouri shore and Illinois shore the average parts per million of free ammonia for the period from January 24th, 1900, to October 10th, 1900, is shown by the following table made from the results obtained by the analysis of the water taken from the Mississippi river at Intake Tower, 300 feet from the Missouri shore and the Illinois shore, respectively:

Date (1900).	Missouri Shore.		Illinois Shore.	
Jan. 24-31	.1208)	Jan. average,	.4920)	Jan. average,
	)	.1208.	)	.4920.
Feb. 1-7	.2200)		.4670)	
Feb. 7-14	.1800)	Feb. average,	.....)	Feb. average,
Feb. 14-21	.1431)	.1673.	.4820)	.4180.
Feb. 21-28	.1260)		.3050)	

Mar. 1-7	.1048)			.3000)	
Mar. 7-14	.1582)	Mar. average,		.2851)	Mar. average,
Mar. 14-21	.1731)	.1457.		.3020)	.2981.
Mar. 21-31	.1468)			.3060)	

Missouri Shore.	Illinois Shore.
April average, .0609	April average, .1776
May average, .0614	May average, .0566
June average, .0416	June average, .0267
July average, .0504	July average, .0291
Aug. average, .0322	Aug. average, .0304
Sept. average, .0454	Sept. average, .0448
Oct. average, .0508	Oct. average, .0448

(Prof. Keiser's testimony, printed record, Volume 2, pages 1021-1022.)

NITRITES.

At the above mentioned place, to wit, Chain of Rocks, samples of water were collected between the Missouri and Illinois shores. The following weekly and monthly average is for nitrites for the period from January 24th to October 10th, 1900:

Date (1900).	Missouri Shore.			Illinois Shore.	
Jan. 24-31	.565)	Jan. average,		1.040)	Jan. average,
	)	.565.		)	1.040.
Feb. 1-7	.457)			.765)	
Feb. 7-14	.457)	Feb. average,		....)	Feb. average,
Feb. 14-21	.542)	.485.		.882)	.790.
Feb. 21-28	....)			....)	
Mar. 1-7	.688)			1.205)	
Mar. 7-14	1.343)	Mar. average,		.822)	Mar. average,
Mar. 14-21	.954)	.935.		1.001)	1.004.
Mar. 21-31	.754)			.980)	
Apr. 1-7	.577)			.977)	
Apr. 7-14	.462)	Apr. average,		1.022)	Apr. average,
Apr. 14-21	.434)	.478.		.897)	.936.
Apr. 21-30	.497)			.851)	

May 1-7	.594)		.600)	
May 7-14	.451)	May average,	.331)	May average,
May 14-21	.371)	.455.	.394)	.435.
May 21-31	.405)		.497)	
June 1-7	.325)		.422)	
June 7-14	.285)	June average,	.388)	June average,
June 14-21	.371)	.364.	.434)	.435.
June 21-30	.474)		.494)	
July 1-7	.423)		.508)	
July 7-14	.423)	July average,	.514)	July average,
July 14-21	.434)	.483.	.514)	.581.
July 21-31	.651)		.788)	
Aug. 1-7	.491)		.514)	
Aug. 7-14	.251)	Aug. average,	.234)	Aug. average,
Aug. 14-21	.314)	.345.	.304)	.419.
Aug. 21-31	.325)		.622)	
Sept. 1-7	.268)		.485)	
Sept. 7-14	.320)	Sept. average,	.505)	Sept. average,
Sept. 14-21	.365)	.358.	.428)	.433.
Sept. 21-30	.480)		.313)	
Oct. 1-10	.617)	Oct. ayerage,	.388)	Oct. average,
	....)	.617.	....)	.388.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1026-1027.)

In the Missouri river at Fort Bellefontaine during the period from January 24th, 1900, to October 10th, 1900, the following results were obtained from chemical analysis of the water of the Missouri at Fort Bellefontaine. Fort Bellefontaine being situated upon the Missouri river about eight miles above its mouth.

CHLORINE.

The monthly averages of chlorine in the waters of the river at Fort Bellefontaine runs as follows:

The average for	January, 1900, was	23.5
"	February	18.6
"	March	12.1
"	April	12.5
"	May	14.5
"	June	11.4
"	July	11.2
"	August	12.8
"	September	16.3
"	October	11.4

(Prof. Keiser's cross-examination, printed record, Volume 2, pages 1104-1105.)

NITRITES.

The average nitrites for the same months is as follows:

The average for 1900 was

January	.008
February	.014
March	.023
April	.018
May	.013
June	.003
July	.001
August	.001
September	.002
October	.002

(Prof. Keiser's cross-examination, printed record, Volume 2, page 1105.)

NITRATES.

The average is as follows:

January	.415
February	.592

March	.965
April	.485
May	.484
June	.418
July	.462
August	.435
September	.381
October	.560

(Prof. Keiser's cross-examination, printed record, Volume 2, page 1105.)

FREE AMMONIA.

The average is as follows:

January	.135
February	.232
March	.144
April	.069
May	.083
June	.067
July	.055
August	.038
September	.068
October	.055

(Prof. Keiser's cross-examination, printed record, Volume 2, page 1105.)

ALBUMINOID AMMONIA.

The average is as follows:

January	.363
February	.395
March	1.182
April	.775
May	1.484
June	1.181
July	1.556

August	.842
September	1.133
October	1.382

(Prof. Keiser's examination, printed record, Volume 2, page 1106.)

In the Mississippi river above Grafton for the same period during the year 1900 the following general average results were obtained: Free ammonia 0.176 parts per million, nitrites 0.005, albuminoid ammonia 0.565.

The Illinois river at Grafton during the same period in the year 1900, disclosed upon examination the following chemical constituents:

FREE AMMONIA.

January	1.498
February	.946
March	.322
April	113
May	.1079
June	.0321
July	.0443
August	.406
September	.0517
October	.0677

NITRITES.

January	.0300
February	.0245
March	.0170
April	.037
May	.0459
June	.193
July	.0352
August	.239

September	.0257
October	.0428

FREE AMMONIA.

Average for the period	.0176

ALBUMINOID AMMONIA.

Average for the period	.565

CHLORINE.

Average for the period, parts per million.	
January	5.7
February	6.1
March	4.5
April	4.8
May	4.2
June	5.1
July	7.7
August	5.2
September	3.3
October	3.9

(Prof. Keiser's examination, printed record, Volume 2, pages 1053-1077.)

In the Illinois river above Grafton for the 1900 period, the following results were obtained by Professor Keiser in his analyses:

NITRITES.

January	.0300
February	.0245
March	.0170
April	.370
May	.0459
June	.193

July	.352
August	.239
September	.0257
October	.0428

FREE AMMONIA.

January	1.498
February	.946
March	.322
April	.113
May	.1079
June	.0321
July	.0443
August	.0406
September	.0517
October	.0677

(Prof. Keiser's examination, printed record, Volume 2, page 1047.)

CHLORINE.

January	14.1
February	13.1
March	7
April	6.1
May	10.9
June	12.6
July	18
August	16.5
September	14.8

(Prof. Keiser's examination, printed record, volume 2, page 1053.)

During this period the average albuminoid ammonia at the place above mentioned was .0193.

(Prof. Keiser's examination, printed record, volume 2, page 1075.)

The following results from the anlyses of the water in the Illinois river at Joliet for the 1900 period is as follows:

NITRITES.

March	.0558
April	.0663
May	.0256
June	.0326
July	.0551
August	.0465
September	.0524
October	.0562
March	2.689
April	2.732
May	2.995
June	3.270
July	3.701
August	2.933
September	4.498
October	3.306

(Prof. Keiser's examination, printed record, volume 2, page 1056.)

Drainage Canal at Lockport for the 1900 period disclosed the following general average results:

NITRITES.

March	.0603
April	.0730
May	.0234
June	.0114
July	.0081
August	.0083
September	.0073
October	.0138

FREE AMMONIA.

March	2.437
April	1.806
May	1.598
June	1.411
July	1.631
August	1.589
September	2.195
October	1.555

Illinois river above Peoria during the same period disclosed the following results:

NITRITES.

February	.0358
March	.0209
April	.0467
May	.0752
June	.1317
July	.1657
August	.1597
September	.1382
October	.1857

FREE AMMONIA.

February	1.416
March	.685
April	.392
May	.266
June	.228
July	.230
August	.142
September	.255
October	1.404

(Prof. Keiser's testimony, printed record, volume 2, pages 1057-1058-1059-1060.)

Prior to the opening of the Canal, during the latter part of the year 1899 and the first few days in January, 1900, the following results were obtained from the analyses of water taken from the respective points, which exhibit a complete change in the chemical condition of the Mississippi river at the Chain of Rocks immediately after the Drainage Canal was opened, and which continued throughout the entire years of 1900 and 1901.

The water taken from the reservoir, St. Louis Waterworks, discloses the following average for the period examined, immediately before the opening of the canal:

Free Ammonia	0.013
Nitrites	0.004
Albuminoid Ammonia	0.214

The Mississippi river at Alton during the period immediately prior to the opening of the canal discloses the following general average results:

Free Ammonia	0.288
Nitrites	0.104
Albuminoid Ammonia	0.200

(Prof. Keiser's testimony, printed record, volume 2, page 1074.)

Missouri river at Fort Bellefontaine, 14 miles from the Chain of Rocks, disclosed the following general average results:

Free Ammonia	0.114
Nitrites	0.013
Albuminoid Ammonia	0.063

(Prof. Keiser's testimony, printed record, volume 2, pages 1077-1078.)

Illinois river at Grafton before the opening of the Drainage Canal discloses the following general average results:

Free Ammonia	0.113
Nitrites	0.005
Albuminoid Ammonia	0.478

(Prof. Keiser's testimony, printed record, volume 2, page 1075.)

The Illinois river at Peoria before the Drainage Canal was opened discloses the following results:

Free Ammonia	0.895
Nitrites	0.141
Albuminoid Ammonia	0.572

(Prof. Keiser's testimony, printed record, volume 2, page 1076.)

During the months of October and November, 1901, the following weekly averages of nitrites were obtained from water taken from Intake Tower, St. Louis Waterworks:

	Parts per Million.
Oct. 1-7	.0037
" 7-14	.0029
" 14-21	.0050
" 21-28	.0048
Oct. 28-Nov. 4	.0131
Nov. 4-11	.0131
" 11-18	.0143
" 18-25	.0130
" 25-30	.0116

(Prof. Keiser's testimony, printed record, volume 1, page 990.)

During the same months, to wit, October and November, 1901, free ammonia contained in the waters of the Intake Tower was in weekly average as follows:

Oct. 1-7 Inc.	.129
" 7-14 Inc.	.051
" 14-21 Inc.	.046
" 28-Nov. 4	.071
Nov. 4-11	.070
" 11-18	.086
" 18-25	.072
" 25-30	.071

(Prof. Keiser's testimony, printed record, volume 1, page 998.)

For the same period, the same water disclosed the following weekly averages of nitrates, expressed in parts per million:

Oct. 1-7	.60
" 7-14	.29
" 14-21	.21
" 21-28	.43
" 28-Nov. 4	.38
Nov. 4-11	.27
" 11-18	.25
" 18-25	.12
" 25-30	.12

(Prof. Keiser's testimony, printed record, volume 1, page 1001.)

In Albuminoid Ammonia the following results were obtained for the same period:

Oct. 1-7 incl.	.855
" 7-14 incl.	.677
" 14 -21 incl.	.523
" 21-28 incl.	.727
" 28-Nov. 4	.553
Nov. 4-11	.493
" 11-18	.794
" 18-25	.536
" 25-30	.420

(Prof. Keiser's testimony, printed record, volume 2, page 1007.)

During the same period the water in the Mississippi river, 300 feet from the Missouri shore, disclosed the following results in nitrites, expressed in parts per million:

NITRITES.

	Missouri Shore.	Illinois Shore.
Date (1901)	Parts per Million	Parts per Million
Oct. 1-7	.0024	.0110
" 7-14	.0027	.0124

" 14-21	.0057	.0144
" 21-28	.0048	.0160
" 28-Nov. 4	.0082	.0123
Nov. 4-11	.0124	.0167
" 11-28	.0141	.0177
" 18-25	.0096	.0171
" 25-30	.0128	.0170

(Prof. Keiser's testimony, printed record, volume 2, page 1018.)

The average quantity of free ammonia found on each side of the Mississippi river in the Intake in October and November, 1901, is as follows:

1901	Missouri Shore	Illinois Shore
Oct. 1-7	.0805	.0869
" 7-14	.0520	.0571
" 14-21	.0449	.0706
" 21-28	.0449	.0557
" 28-Nov. 4	.0717	.0957
Nov. 4-11	.0634	.0714
" 11-28	.0894	.0720
" 18-25	.0810	.0489
" 25-30	.0844	.0648

(Prof. Keiser's testimony, printed record, volume 2, pages 1025-1026.)

NITRATES.

1901		1901
Missouri Shore		Illinois Shore
Oct. 1-7	.428	.485
" 7-14	.428	.291
" 14-21	.240	.269
" 21-28	.377	.331
" 28-Nov. 4	.400	.360
Nov. 4-11	.234	.497
" 11-18	.257	.257

" 18-25	.260	.291
" 25-30	.184	.223

(Prof. Keiser's testimony, printed record, volume 2, page 1030.)

The weekly average of nitrates in water of the Mississippi river, Chain of Rocks, Illinois Shore at Hartford and Alton, during the months of October and November, 1900:

Date	Illinois shore Chain of Rocks.	Hartford.	Alton.
October 1 to 7	.0110	.0235	.0160
October 7 to 14	.0124	.0184	.0121
October 14 to 21	.0144	.0150	.0180
October 21 to 28	.0160	.0163	.0190
October 28 to November 4	.0123	.0137	.0102
November 4 to 11	.0167	.0191	.0103
November 11 to 16	.0177	.0190	.0124
November 18 to 25	.0171	.0167	.0072
November 25 to 30	.0170	.0186	.0088

(Prof. Keiser's testimony, printed record, volume 2, page 1040.

Samples of water taken from the Chicago Drainage Canal, extending from October 9th to November 30th, 1901, disclosed the following chemical constituents:

NITRITES.

October	9th	Nitrites	.016
"	10th	"	.040
"	11th	"	.018
"	12th	"	.017
"	13th	"	.036
"	14th	"	.015
"	15th	"	.017
"	16th	"	.018
"	17th	"	.018
"	21st	"	.019

"	22nd	"	.027
"	23rd	"	.013
"	24th	"	.016
"	26th	"	.015
"	27th	"	.014
"	28th	"	.025
"	29th	"	.016
"	30th	"	.019
"	31st	"	.018

November 1, 1901, Nitrites parts per million.

November	1st	Nitrites	.028
"	2nd	"	.016
"	3rd	"	.017
"	4th	"	.013
"	5th	"	.017
"	6th	"	.015
"	7th	"	.018
"	8th	"	.028
"	9th	"	.015
"	10th	"	.015
"	11th	"	.013
"	12th	"	.025
"	13th	"	.015
"	14th	"	.015
"	15th	"	.027
"	16th	"	.016
"	17th	"	.023
"	18th	"	.015
"	19th	"	.016
"	21st	"	.007
"	22nd	"	.013
"	23rd	"	.018
"	24th	"	.017
"	26th	"	.017
"	27th	"	.017
"	28th	"	.016

"	29th	"	.017
"	30th	"	.015

(Prof. Keiser's testimony, printed record, volume 2, pages 1060-1061.)

CHLORINE.

October	9th	Chlorine	22.8
"	10th	"	23.0
"	11th	"	18.0
"	12th	"	12.1
"	13th	"	20.8
"	14th	"	21.0
"	15th	"	19.0
"	16th	"	23.2
"	17th	"	19.5
"	21st	"	22.3
"	22nd	"	22.5
"	23rd	"	17.5
"	24th	"	18.2
"	26th	"	22.0
"	27th	"	21.3
"	28th	"	21.7
"	29th	"	23.8
"	30th	"	29.0
"	31st	"	24.2
November	1st	"	21.5
"	2nd	"	23.0
"	3rd	"	13.8
"	4th	"	13.2
"	5th	"	11.3
"	6th	"	10.0
"	7th	"	16.0
"	8th	"	12.0
"	9th	"	10.8
"	10th	"	14.2
"	11th	"	14.8
"	12th	"	10.6

"	13th	"	12.2
"	14th	"	9.0
"	15th	"	8.0
"	16th	"	11.0
"	17th	"	11.0
"	18th	"	9.0
"	19th	"	11.2
"	21st	"	8.
"	22nd	"	11.9
"	23rd	"	11.3
"	24th	"	12.3
"	26th	"	9.0
"	27th	"	11.6
"	28th	"	16.1
"	29th	"	16.2
"	30th	"	29.0

(Prof. Keiser's testimony, printed record, volume 2, pages 1062-1063.)

FREE AMMONIA.

October	9th	Free Ammonia	.328
"	10th	"	2.860
"	11th	"	.676
"	12th	"	.812
"	13th	"	1.66
"	15th	"	1.072
"	16th	"	1.500
"	17th	"	.884
"	21st	"	.672
"	22nd	"	.334
"	23rd	"	.884
"	24th	"	.796
"	26th	"	.732
"	27th	"	1.020
"	28th	"	1.288
"	29th	"	.744
"	30th	"	.700
"	31st	"	.744

November	1st	Free Ammonia	.968
"	2nd	"	.628
"	3rd	"	.648
"	4th	"	.988
"	5th	"	1.068
"	6th	"	.568
"	7th	"	.652
"	8th	"	.436
"	9th	"	.452
"	10th	"	.849
"	11th	"	.560
"	12th	"	5.192
"	13th	"	.568
"	14th	"	.640
"	15th	"	.468
"	16th	"	.428
"	17th	"	.588
"	18th	"	.452
"	19th	"	.560
"	21st	"	.716
"	22nd	"	.564
"	23rd	"	.504
"	24th	"	.628
"	26th	"	.404
"	27th	"	.968
"	28th	"	.256
"	29th	"	1.892
"	30th	"	2.140

(Prof. Keiser's testimony, printed record, volume 2, pages 1063-1064.)

The chemical analyses made by Professor Keiser disclosed that early in February, 1900, quantities of nitrites in the water of the St. Louis Reservoir began to increase materially, and was, from that date on, in a very high polluted condition. This abnormal increase in nitrites is attributed to large quantities of sewage coming down the Mississippi river, and from the analysis

made at other points along the Mississippi and Illinois rivers it will be observed that this sewage came down the Illinois river from Chicago.

(Prof. Keiser's testimony, Volume 1, pages 988-989 and 997.)

The chemical analyses made by Professor Keiser shows clearly that for the period beginning January 24, 1900, to October 10, 1900, and from thence on, the water in the Mississippi river, at Chain of Rocks, became suddenly badly polluted about the first week, and has since so continued to be polluted. This is shown by the large increase in quantity of free ammonia and nitrites in the reservoir water throughout the entire period traceable under the chemical observation made by Professor Keiser of the Illinois river and the Chicago Drainage Canal.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1007-1008.)

Another remarkable fact is shown by these chemical observations, to wit, that the water in the Missouri river was less contaminated with sewage pollution than the Mississippi and the Illinois rivers, and that during the entire period of the investigation larger quantities of chemical constituents were found in the Mississippi river near the Illinois shore than on the Missouri shore, and larger quantities were found near the Intake, 1,500 feet from the Missouri shore, than were found at the Missouri shore. The quantities found on the Illinois shore at the Intake being considerable larger than those contained in the samples of water in Fort Bellefontaine.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1018-1019-1020.)

It is also apparent that the Mississippi river above the mouth of the Illinois was in much better condition than the Illinois river at its mouth or the Mississippi river below the mouth of the Illinois.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1033-1034-1035-1036.)

The sewage contamination of the Illinois river is shown to have gradually increased as the stream is ascended until the Chicago Drainage Canal is reached.

(Prof. Keiser's testimony, printed record, Volume 2, page 1040.)

At Joliet and Lockport the analysis of the water shows the water to be sewage. The results for free ammonia and nitrites being such as are obtained from analyzed sewage. Before the opening of the canal the movement in the Illinois river was much slower than afterwards. In the examinations made prior to the opening of the Canal it shows that oxidation had proceeded much further, and after the opening of the Drainage Canal the quantity of nitrites increased enormously, and kept on increasing throughout the time the examinations were made.

The effect of the opening being to wash out the oxidation materials and carry them further down the river.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1044-1045-1046-1047.)

Professor Keiser stated in his judgment as a chemist and from his chemical examination of the waters in question, that the pollution and contamination of the sewage of Chicago passed down the Illinois river through the Chain of Rocks, a portion of it finding its way into the Intake Tower of the St. Louis Waterworks, and thence into the reservoir. The water supply of the city of St. Louis being thereby contaminated with the sewage of Chicago, discharged into the Chicago Drainage Canal, and thence into the Des Plaines and Illinois rivers. The volume of water since the opening of the canal in the Illinois river, having been very greatly increased, produces the effect of disposing of the sewage of Chicago very rapidly by carrying and pushing it down the Illinois river. In fact, it is caused to be pushed down the Illinois river into the Mississippi river in great quantities. This increased velocity of the water has a tendency to destroy the process of sedimentation. Sedimentation, therefore, is much less in the Illinois river now than it was prior to

the opening of the canal, for the reason that there is a more rapid current which carries the suspended matters along with the stream and gives less opportunities for sedimentation.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1048-1049.)

The average results of Prof. Teichman's daily analysis for the period from January 23rd to October 11, 1900, at Lockport, from water collected, show free ammonia, 1.585 parts per million, nitrites .026 parts per million. These high results of nitrogen are followed by a corresponding rise of high results in the Illinois river three miles above Grafton during the same period, and clearly show the enormous pollution caused by the flushing out of the Chicago river and the Drainage Canal, and carrying forward into the Illinois river enormous quantities of organic matter, the conditions for self-purification being practically impossible. This fact is more particularly demonstrated by a careful observance of the chemical analyses of the water in the Illinois river throughout its entire length during the months of January and February, 1900, immediately after the opening of the Chicago Drainage Canal. It will be noticed that in January, immediately after the opening, the chlorines at Peoria increased to 28 parts per million, which is followed by an increase at Grafton from 15 to 23 parts per million. With reference to free ammonia, the same conditions obtained at Peoria and Grafton as in the case of chlorine, immediately following the opening of the canal. A corresponding increase is observed from the city of Chicago until the water reaches the Mississippi at Grafton.

(See Teichmann's testimony, Volume 2, pages 1206-7-8.)

What is said with reference to an increase in free ammonia and chlorine may also be applied to nitrites. During the period from January until October, 1900, there is a significant correspondence of the fluctuations in nitrites at the various points upon the Illinois river. During this investigation it was also discovered, as is shown by the chemical analyses, that the waters

of the Illinois river were in a peculiarly unsuitable character as compared with the waters of the Mississippi river above Grafton, the point of entrance of the Illinois. One of the most conclusive tests of the effect of the Illinois river water upon the Mississippi river water is shown by the chlorine properties of the respective rivers, which, when considered along with the increase in free ammonia and nitrites, bear us onward to the inevitable conclusion that the increased pollution of the Mississippi river below Grafton is due to the discharge of nitrogenous animal matter into the waters. The chlorines are observed to be much lower in the Mississippi river above Grafton than in the Illinois, and the chlorines in the Illinois prior to the opening of the Drainage Canal were much lower than since the opening. Below Grafton the Mississippi river is shown to have increased materially in chlorines, and this, too, at a point above the entrance of the Missouri, so that the large quantities of chlorines contained in the Missouri river are not to be considered as producing a material effect. Thus, considering the high chlorines in the Missouri, accompanied with low free ammonia and nitrites, we conclude that the polluting matter contained in the Missouri river is due to vegetable decomposing matter, and to salt derived from the salt beds drained by the Missouri river, rather than from animal origin. This being true, the increase in chlorines, free ammonia and nitrites in the waters of the Mississippi river at the intake, demonstrate clearly and forcibly that the increased pollution is due to the effect of the opening of the Drainage Canal upon the waters of the Illinois river.

(See Teichmann's testimony, Volume 2, pages 1209-10-1211-15-16-17-18-19-20-21-22.)

In the chemical observations of the water supply, the following conditions may be said to have been by long experience found to exist: First, high free ammonia, high nitrites, and high chlorine indicate sewage pollution. The foregoing is of course conditioned upon the hypothesis that the watershed of the stream examined is populated, and that there are no salt beds of importance upon the watersheds; second, high free ammonia, high nitrites and high chlorine, with low nitrates, indi-

cate sewage pollution in its earlier stages; third, low free ammonia and low nitrites, with high chlorines indicate vegetable pollution with salt beds located upon the watershed of the river examined; fourth, low free ammonia, low nitrites and high chlorine and high nitrates indicate that the water examined may have been sewage polluted, but has traveled sufficient distance and under such favorable circumstances as to largely reduce the organic matter, and thereby, to some extent, free the river of its polluting substances, but does not necessarily indicate that the disease producing organisms, or the pathogenic bacteria have disappeared from the water.

(See Keiser's testimony, Vol. 2, pp. 1012, 1013, 1019, also Teichmann's testimony, Vol. 2, pp. 1212, 1213, 1225, 1653, 1654, 1655, 1656, 1691; also Keiser's testimony, Vol 2, pp. 1724-5.)

The terms nitrates, nitrites, albuminoid and free ammonia are defined by Mr. Whipple in his testimony in Vol. 3, pp. 2060 to 2063.

From the testimony above referred to, together with the chemical analyses made from samples collected from the respective waters, it will be observed, first, that the waters of the upper Mississippi river, to-wit, above Grafton, contain low free ammonia, low nitrates, and low chlorine, and the waters of the Missouri river also contain low free ammonia and low nitrites, with high chlorines, the nitrates and free ammonia being much lower in the Missouri river than in the upper Mississippi, while the waters of the Illinois river at its mouth contain high free ammonia, high nitrites and high chlorines, and this apparent pollution continually increases as the river is ascended until the Chicago Drainage Canal is reached, where the chemical analysis showed enormous quantities of constituents which are carried into the canal from the sewers of Chicago. This increase in pollution of the Illinois river is shown to be due to the sewers of Chicago and not from any city located upon the natural watershed of the Illinois river or from the tributaries of that river, the analyses of the waters in the tributaries show-

ing the condition much improved over that existing in the Illinois river itself.

10.

DISAPPEARANCE OF BACTERIA IN RIVERS.

There are several reasons given by scientists for the gradual disappearance of bacteria in the water.

AERATION.

Which means adding air to the water, and it was formerly thought that the oxygen of the air was injurious to the bacteria. It is known that the oxygen in the water causes the anaerobic bacteria to cease their activity, but later experiments have shown that agitation and aeration do not kill the bacteria and consequently do not reduce the number.

DILUTION.

The investigation made in this case shows that the Des Plaines river and other rivers, as the water flows along from the Drainage Canal, are added to the total quantity of bacteria passing over the dam. This of course produces dilution. In other words, it may be demonstrated in the following way. A quart of water contained 100 bacilli, added to 99 quarts of water, which result in one bacilli to one quart of water, the dilution in this way removed the bacilli further apart so that in taking a particular sample or quantity of water from the main force, we get a less number of bacteria to a definite quantity of water.

The bacteria, however, are all there, but simply removed further apart by the quantity of water that is added to it.

EFFECT OF THE SUNLIGHT.

During the experiments made in this investigation an opportunity was given to determine to some extent the effect of the

sunlight upon the bacteria, especially bacilli typhosus. There was very little difference noted in the numbers of bacteria in samples collected between bright sunshiny days and the gloomy and foggy days. The depth that the sunlight can penetrate to the injury of bacteria is not very great. It is more in clear water than in turbid waters. In summer days the action of the rays of the sun may be said to be more active than in winter days, but these determinations, however, show the sunlight has very little to do with decreasing the number of bacteria in a given quantity of water.

SEDIMENTATION.

Bacteria are particles. They have weight, not very great, but still those that can not swim are gradually carried to the bottom of the stream, and where the stream flow is not rapid, sedimentation of course becomes, to some extent, greater. This, however, does not mean that the bacteria are dead. It simply means that they have been carried to the bottom of the stream and remain in muck and slime at the bottom of the stream until carried away by refreshing or a larger body of water.

SEPTIC ACTION.

When the water becomes perfectly quiet and is permitted to stand for considerable length of time,. septic action takes place, and where the stream or body of water is highly polluted the septic action has powerful effect upon the bacterial contents of the water. In fact, in a short time all bacterial growth is destroyed.

EXHAUSTION OF FOOD SUPPLY.

It has been suggested by some that the food supply of the bacteria in a body of water becomes exhausted and therefore causes the bacteria to perish. This theory, however, as applied to pathogenic bacteria, is not considered of much importance. It may be said that dilution and sedimentation really constitute the

prime factors and the real cause of bacteria in running streams. In neither case can it be said that the bacteria are destroyed in dilution, they are removed further apart, while in sedimentation they remain in the bottom of the stream until taken up and carried down by an increase of the velocity of the water.

(Printed record, Volume 1, pages 809-812.)

The dilution of sewage or water contaminated by sewage removes the infected material further apart, but does not destroy it, in fact the witnesses agree that instead of destroying infectious germs it has a tendency to prolong their life.

(Sedgwick's testimony, Vol. 3, page 2217.)

11.

MICROSCOPIC OBSERVATIONS OF THE WATERS OF LAKE MICHIGAN, CHICAGO DRAINAGE CANAL, AND ILLINOIS AND MISSISSIPPI RIVERS.

In October and November, 1901, Mr. Geo. C. Whipple made microscopic examinations from one hundred and thirty-six samples of water taken from Lake Michigan, Chicago Drainage Canal, from the Illinois river, from the tributaries to the Illinois river, Mississippi above Grafton, Mississippi at Alton, Mississippi at Ft. Bellefontaine and the Mississippi at the Chain of Rocks, Intake tower, and on the Mississippi and Illinois shores near the St. Louis waterworks. Strictly speaking, microscopic organisms contained in the water are very minute particles of substance, minute forms of life, too small to be identified without the use of the microscope, but large enough to be studied without the use of artificial cultures, as in the case of bacteria. Microscopic organisms belong some to the plant kingdom and some to the animal kingdom, although among the forms it is somewhat difficult to draw the distinction between animals and plants; while bacteria are all determined as belonging to the vegetable kingdom and constitute vegetable matter. Some of the microscopic organisms might die out during the period of

transit, or while contained in the water, others might possibly develop during transit, while others still, would probably remain unchanged; at any rate, they would not increase in number nor would they disintegrate to such extent as to be unrecognizable. In these determinations Mr. Whipple found the organisms known as synedera pulchella, variety sub-prolongata to largely exist in the waters of Lake Michigan, but not found in the waters of its tributaries or the Mississippi and Illinois rivers. This variety was also found in the waters of the Mississippi at the Intake, demonstrating clearly that it passed from Lake Michigan down the Illinois river to the intake at the Chain of Rocks. Several other varieties, natural to Lake Michigan water, but not found to any considerable extent in the waters of the Mississippi above Grafton tributary to the Illinois or the Missouri, were observed in the waters collected from the Mississippi at the Chain of Rocks, demonstrating that living organisms contained in the waters of Lake Michigan passed through the canal into the river and thence into the Mississippi and the intake of the St. Louis Waterworks.

(See Whipple's testimony, Vol. 2, page 1909, and Complainant's Exhibits 46, with the sub-numbers one to fourteen, inclusive. See also, Whipple's testimony, pp. 1932, 1995-6.)

It might be well in this connection to state that Dr. Ravold, in his examination of the respective waters involved in this case, detected certain forms of vegetable life in the waters of the Mississippi river at the Intake and in the reservoir water of the city of St. Louis, which naturally inhabit the waters of Lake Michigan, but which are not found in the waters of the Missouri, Mississippi or the tributaries of the Illinois.

(See Ravold's testimony, Vol. 1, pp. 316 to 360, inc.)

12.

PRODIGIOSUS.

The bacillus prodigiosus is a micro-organism discovered by Ehrenberg. It is a little larger than the typhoid bacillus. It is

non-spore forming and non-pathogenic. It is founded on the word "prodigious," and comes from the fact that the host sometimes in the chalice in the Catholic church has a red growth upon it, which is declared to be the blood of Christ. This red growth was investigated, and it was found to be a micro-organism, producing a red material within its cell. It grows freely on all media, but does not grow in the river water. It has been rarely found in the river waters of this country, and it is not common to the domestic waters of the United States, although it is said to be found in abundance in some of the waters of Egypt. It liquifies gelatine and is non-motile.

In the examination made in the waters of the respective rivers in August, 1899, and extended through until August, 1900, every sample was closely inspected for the purpose of disclosing the distinctive form of micro-organism found. In none of the samples could the bacilli of prodigiosus be found. The conclusion was therefore reached that it was not a normal inhabitant of the streams under investigation. Ten thousand samples of water have been examined without it having been found. On the 31st day of August, 1900, a forty-gallon whiskey barrel, containing forty gallons of broth culture of bacilli prodigiosus, containing over one thousand million bacteria per cubic centimeter, was emptied into the Mississippi river just below the mouth of the Illinois river.

On the 3rd day of September, three days later, this organism was found in a sample of water collected in the river at Alton.

On September 20th the experiment was repeated: A barrel containing forty gallons of bacillus prodigiosus broth was emptied at the same point, and on the 23rd of September the organism was found in a sample of water collected on the Illinois shore at the Chain of Rocks.

On October 18th this bacterium was found in a sample of water from the laboratory tap in the old City Hall, St. Louis.

On October 24th it was found in a sample collected on the Illinois shore, Chain of Rocks.

On the evening of November 6, 1901, 107 barrels of prodigiosus broth, containing forty gallons each, with over one thou-

sand million prodigiosus bacteria per cubic centimeter, were deposited in the Chicago Drainage Canal a few miles east of the Bear Trap Dam at Lockport.

On December 4, 1901, bacilli prodigiosus was found in a sample of water collected from Intake Tower, Chain of Rocks, and in another sample collected from the same place on December 5th.

On December 6, 1901, it was found in a sample collected at Grafton, Illinois.

On December 7, 1901, it was found in a sample collected from the Illinois river at Grafton.

Dr. Ravold made experiments as to the longevity of the bacilli prodigiosus in samples of water collected in the Chicago river, Drainage Canal, Illinois river at Peoria and the Laboratory tap at St. Louis. It was found to live in the non-sterilized water of Drainage Canal at Joliet seven days and Chicago river eleven days. In the Drainage Canal at Lockport thirty-two days. In the Illinois river at Pekin fifty-three days.

In the refrigerator in the dark it was found to live for a period of thirty-one to fifty-three days, and in the above non-sterilized water, exposed to sun light, it survived eleven days, while the bacilli typhosus in the same water, under similar circumstances, lived from ten to twenty-one days.

(Dr. Ravold's testimony, printed record, Volume 1, pp. 779-788, inc.)

During the period of the above investigation the waters were cold and there was no opportunity for multiplication of the bacilli.

(Dr. Ravold's testimony, printed record, Volume 1, p. 920.)

A careful examination was made, so that no mistake could be made, as to whether or not the bacilli discovered were those of prodigiosus, as shown by the following excerpt from the cross-examination of Dr. Ravold.

"We allowed the plates to rest as long as possible, to gather the red color, and the plate might liquify before the color ap-

pears. It is impossible to say anything about the number on a plate.

"*Q. When you discovered the red color you had accomplished all you were looking for and ceased.*

"*A. No, the red color was an indication that a bacillus producing a red pigment was there; that bacillus had to be separated out in a pure culture and put through all its cultural characteristics and studied for form. In fact we searched thoroughly to see whether it was the one we put in the canal or not, and compared it with the ones put in.*

"Q. Were you able to identify it as the genuine article?

"A. It had no label on it; no name blown on the bottle, or anything of that kind, but it behaved like the original culture.

"Q. It was of good behavior, was it?

"A. Yes, sir.

"Q. Doctor. have you ever examined any of the waters on this continent for the purpose of ascertaining the presence of the bacillus prodigiosus other than that which you have just mentioned?

A. "No, sir, I have never undertaken such a tremendously extensive investigation as was included in this work on the Drainage Canal and the Illinois river, but I have never found it in any of the waters which I have examined in this country, and my laboratory assistant, my associate, was Mr. Johnson, as clever a water bacteriologist as there is in this country. He worked continuously on the Ohio river above Louisville and Cincinnati, for two or three years and did not find it in that water, and I understand that a bacteriologist who worked at New Orleans—one of them told me this—that he once found the prodigious in the Mississippi river near New Orleans, after we had emptied it into the Drainage Canal.

"Q. And then as far as your knowledge extends, and from personal knowledge and from information of others, all examinations on this continent heretofore have not revealed the presence—

"A. Not in large numbers.

"Q. —of this bacteria?

"A. I would say it has been found a very few times—I searched the literature on the subject—in the waters of the United States.

"Q. What were the peculiar characteristics of this bacterium that enabled you to identify it?

"A. It is one of the most easily identified of all bacteria.

"Q. In what respect?

"A. In its pigment production.

"Q. Color?

"A. The pigment that it produces. It liquifies gelatine and produces pigment; it coagulates milk and turns that milk red without digesting the casein which is the result of the coagulation, and makes it very characteristic at once.

"Q. But all bacteriological examinations carried on with the view to ascertaining the quantitative presence of bacteria in running water or lake waters reveal the presence of this bacterium?

"A. Yes, sir.

"Q. They would?

"A. Oh, yes; every man who studies water quantitatively. Every bacteriologist is mad in the search of new forms. He wants to have a bacillus named after him if he can, or he wants to find one and name it. He wants to have his name go down in literature as associated with a bacterium—every man that plates a specimen of water is searching that water constantly for new forms.

"Q. Well, doctor, there are a great many examinations of this kind that have been carried on in recent years?

"A. Yes, sir.

"Q. All over this country?

"A. All over this country.

"Q. And you will not say that no other bacteriologist than those you have mentioned, and yourself, have not found this—

"A. Oh, no.

"Q. —particular bacterium in the waters of the United States?

"A. No, I couldn't say that.

"Q. You simply haven't found it, and those with whom you have conversed, whose names you have mentioned, have not found it?

"A. I see also from your investigation, the book published by the State Board of Health of Illinois, I don't see the prodigiosus named among the bacteria found by the Northwestern men.

"Q. In the waters of the Illinois river?

"A. Yes, although they have got quite a number of bacteria separated out, as distinctive for these waters.

"Q. That report, however, did not include any specimens taken from the waters of Lake Michigan, did it, with the view to this particular bacteria?

"A. I don't know whether it did or not.

"Q. Have you ever made any examinations of the waters of Lake Michigan?

"A. Yes, sir; oh, yes.

"Q. Did you make that examination in connection with this investigation?

"A. Yes, I have had samples collected, and the water was studied thoroughly, and I gave you the—

"Q. All the flora?

"A. I gave you all the bacteriological flora found by us in the Lake Michigan water. That has already been submitted in evidence.

"Q. And you didn't find in those examinations any evidence of the presence of the bacillus prodigiosus?

"A. No, sir; nor in the Chicago river, or the Drainage Canal.

"Q. You have stated all that in your previous examination?

"A. Oh, yes; that has already been gone over.

"Q. That is all in the record?

"A. Yes, sir.

"Q. Now, what is your opinion as to the probability of reproduction or multiplication of numbers of the bacillus prodigiosus after being deposited in the waters of the Drainage Canal?

"A. As I said before, that point was kept clearly in mind before the bacteria were deposited—the water was cold, almost to the freezing point, before the bacteria were put into the water. We felt perfectly confident that there would be no multiplication of micro-organisms under these conditions of temperature and nutritive pabulum, etc., which would surround the bacteria in the waters of the Drainage Canal or the Illinois river.

"Q. So then, it is your opinion—

"A. So it is my opinion that these micro-organisms did not multiply in the transit from the point where they were put into the canal to the Intake, and if they did so, it was very feebly so because they do not multiply under the conditions named; they do not multiply below 10 degrees centigrade.

"Q What would be the temperature of your water mains in reference to their possibility of reproduction?

"A. Here?

"Q. Yes, in the city of St. Louis?

"A. Well, the temperature of the water running from the tap at that particular time; I don't remember, but we took the temperature of the water from the tap during this period and that is on record. I haven't the record with me, but the temperature would be higher than in the water of the running stream.

"Q. It would not be quite so cold?

"A. No.

"Q. But would it be up to a point at which there would be a probability of reproduction or multiplication of species?

"A. Not the production, no. It was low, but above freezing."

(Dr. Ravold's cross-examination, printed record, Vol. 1, pp. 923-924-925-926-927.)

Mr. Whipple, at page 2002, stated his unqualified opinion to be that the bacilli prodigiosis discovered in samples of water collected at the mouth of the Illinois river, and at the St. Louis waterworks by Dr. Ravold and his assistants, constituted a portion of the bacilli which were contained in the hundred and six

barrels of bacilli prodigiosis deposited in the Chicago drainage canal at Lamont. (Vol. 2, page 2002.)

This opinion was concurred in by Prof. Sedgwick in the following words:

"This interesting and valuable experiment, as I regard it, seems to me to show that typhoid germs might pass from the drainage canal through the Des Plaines and Illinois rivers, and be carried alive to the intake at the Chain of Rocks, and then to the supply of water, thereby producing typhoid fever at the city of St. Louis. (Vol. 3, page 2204.)"

13.

THE MISSOURI RIVER IS SUBJECTED TO THE DRAINAGE FROM SALT BEDS IN KANSAS, THUS PRODUCING LARGE QUANTITIES OF CHLORINE IN THE RIVER.

In the chemical analysis of the waters of the respective rivers it was found that the Missouri river contains more chlorine than the upper Mississippi, and some less than the waters of the Illinois, and much less than the waters of the Illinois river at La Salle, Peoria and elsewhere. The chlorine in the Mississippi river is explainable from the fact that it runs on an average with the chlorines of other rivers having similar pollutions sewering into it. The large quantities of chlorine in the Illinois river are explainable only from the immense population of Chicago, and the Sanitary District of Chicago, there being no salt beds upon the watershed of either the Illinois or the Mississippi rivers. It is a well known historical fact that upon the Missouri river are situated large beds of salt, ranging in depth from ten to more than three hundred feet.

In a tabular presentation of salt deposits of the United States, published by the United States under the title, "Useful Minerals of the United States," we find the following on page 732:

"Common salts, brines and rock salts, extensive deposits in the central part of Kansas, at Ossawatomie, several wells near Hammond, in Brown County, brines in the valley of Fall river, brine in wells at Mound city, Lynn county, State Salt Springs and other salt marshes in the belt crossing Solomon, Republican and Saline counties, eighty by thirty-five miles, rock salt in beds six to twenty-eight inches deep, with salt industries at Solomon City, Saline county; Junction City, Davis county; rock salt at Anthony, seventy-five feet thick, in Harper county, many borings at Ellsworth, one hundred and forty feet thick, and at Lyons two hundred and fifty feet thick.

The above Republican river, Solomon river and Saline valleys are tributary to the Kaw river, which is three hundred miles long and drains through several of the counties containing large deposits of salt and empties into the Missouri river at Kansas City.

(See Teichmann's testimony, Vol. 2, page 1690; Keiser's testimony, Vol. 2, pp. 1722-3-4-5, and Whipple's testimony, Vol. 3, page 2091.)

14.

MIXING OF THE ILLINOIS, MISSOURI AND MISSISSIPPI RIVER WATERS AT AND ABOVE THE CHAIN OF ROCKS.

That the water of the Illinois river mixes with the water of the Mississippi river below Grafton is clearly demonstrated by examination of the chlorine contained in the waters of the respective rivers. It will be found that the chlorine on the Missouri shore is higher than the chlorine at the Intake tower, demonstrating that the water at the intake tower is not altogether Missouri river water because the Missouri river contains a larger quantity of chlorine than the Mississippi. It is also shown that the chlorines at the Intake are higher than the chlorines in the water in the Mississippi above Grafton. It therefore becomes conclusive that the large quantity of chlorine entering at the Intake must come from the Illinois river, the Illi-

nois river above Grafton containing a larger quantity than the Missouri or Mississippi. (See Teichmann's evidence, Volume 2, 1221-2-3.)

The mixing of the water of the Mississippi and Missouri rivers was determined by Prof. Teichmann, based upon the total of solids contained in samples of water collected from the Mississippi and Missouri rivers. The table of percentages from January 24, 1900 to October 10, 1900, is as follows:

Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
January	24	220	73	27
	25	90	56	4
	26	305	78	22
	27	280	87	13
	28	230	100	0
	29	170	53	47
	30	250	69	31
	31	210	78	22
February	1			
	2	120	58	42
	3	70	58	42
	4	80	62	38
	5	140	93	7
	6			
	7	0	0	100
	8			
	9	60	22	78
	10	200	38	62
	11			
	12	80	53	47
	13	370	65	35
	14	510	77	33
	15	700	88	12
	16	1785	98	2
March	4	190	79	21
	8	1810	79	21
	9	720	57	43

Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
	10	980	67	33
	11			
	12	1225	53	47
	13	1680	67	33
	14	1895	81	19
	15	1870	68	32
	17	1410	62	38
	18	1140	52	48
	20	350	31	69
	21	470	80	20
	22	114	9	91
	23	85	11	89
	24	...	0	100
	25	...	0	100
	26	...	0	100
	27	...	0	100
	28	...	0	100
	29	188	38	62
	31	...	0	100
April	1	80	12	88
	2	410	50	50
	3	400	44	56
	4	380	37	63
	5	480	44	56
	6	720	68	32
	7	...	100	0
	8	675	55	45
	9	690	52	48
	10	820	65	35
	11	650	55	45
	12	630	45	55
	13	790	52	48
	14	1695	67	33
	15	...	100	0
	16	...	100	0

Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
	17	1441	45	55
	18	1383	70	30
	19	1078	54	46
	20	884	45	55
	21	1153	63	37
	22	822	21	79
	23	1154	78	22
	24	739	65	35
	25	44	9	91
	26	906	82	18
	28	934	63	37
	29	870	68	32
	30	782	80	20
May	1	790	66	34
	2	840	67	33
	3	990	71	29
	4	1155	61	39
	5	1070	49	51
	6	430	26	74
	7	955	60	40
	8	358	42	56
	9	845	62	38
	10	745	51	49
	11	717	59	41
	12	810	56	44
	13	1431	82	18
	14	1737	55	45
	15	1700	66	34
	16	1545	79	21
	17	1480	72	28
	18	1645	68	32
	19	1851	90	10
	20	1440	87	13
	21	1495	81	19
	22	1487	86	14

Date 1900	Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
23	1467	82	18
24	1481	83	17
25	1402	83	17
26	1377	75	25
27	1303	81	19
28	1478	100	0
29	1702	94	6
30	1865	89	11
31	...	100	0
June 1	1680	94	6
2	1615	74	26
3	1845	95	5
4	...	100	0
5	1695	85	15
6	1660	86	14
7	1540	79	21
8	1433	72	28
9	1630	81	19
10	1605	75	25
11	1515	95	6
12	...	100	0
13	1620	94	6
14	3635	91	9
15	...	100	0
16	...	100	0
17	...	100	0
18	2072	94	6
19	...	100	0
20	1670	91	9
21	1795	94	6
22	2740	93	7
23	...	100	0
24	...	100	0
25	...	100	0
26	...	100	0

Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
	27	2685	99	1
	28	2415	84	16
	29	...	100	0
	30	...	100	0
July	1	...	100	0
	2	...	100	0
	3	...	100	0
	4	...	100	0
	5	2660	74	26
	6	...	100	0
	7	...	100	0
	8	...	100	0
	9	...	100	0
	10	3070	88	12
	11	...	100	0
	12	...	100	0
	13	...	100	0
	14	...	100	0
	15	...	100	0
	16	2135	94	6
	17	1990	92	8
	18	1570	77	23
	19	1973	95	5
	20	1440	86	14
	21	1430	87	13
	22	...	100	0
	23	2416	99	1
	24	2900	81	19
	25	3090	73	27
	26	2869	85	15
	27	2020	76	24
	28	1921	84	16
	29	...		
	30	1587	83	17
	31	1460	94	6

Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
August	1	1273	79	21
	2	1312	100	0
	3	1238	82	18
	4	1248	87	13
	5	999	78	22
	6	1078	89	11
	7	743	61	39
	8	764	77	23
	9	703	75	25
	10	701	75	25
	11	730	75	25
	12	655	81	19
	13	598	78	22
	14	604	75	25
	15	590	81	19
	16	576	75	25
	17	575	67	33
	18	630	90	10
	19	778	73	27
	20	988	85	15
	21	900	65	35
	22	860	73	27
	23	760	71	29
	24	782	85	15
	25	736	76	24
	26	736	76	24
	27	820	94	6
	28	977	85	15
	29	951	83	17
	30	750	50	50
	31	750	50	50
September	1	885	94	6
	2	1030	99	1
	3	969	82	18
	4			

Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
	5	1124	72	28
	6	1175	96	4
	8	1082	84	16
	9	1056	87	13
	10	900	83	17
	11			
	12	674	60	40
	13	708	73	27
	14	583	67	33
	15	598	74	26
	16	555	60	40
	17	570	67	33
	18	553	60	40
	19	524	60	40
	20	659	56	44
	21	1069	57	43
	22	1597	54	46
	23	1593	60	40
	24	1650	59	41
	25	1476	67	33
	26	1320	65	35
	27	920	66	34
	28	975	64	36
	29	925	68	32
	30	973	68	32
October	1	913	65	35
	2	965	59	41
	3	1542	61	39
	4	877	36	64
	5	1642	72	28
	6	1519	72	28
	7	1567	58	42
	8	1521	68	32

Date 1900	Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
9	1740	77	23
10	1791	74	26

(Teichmann's testimony, Vol. 2, page 1240.)

Prof. Keiser, at page 1050 of his testimony, also made determinations as to the percentage of Mississippi river water entering the intake of the St. Louis water supply as compared with the amount of Missouri river water entering it.

See also Whipple's testimony, Vol. 2, pp. 1982-3-1991-2151.

By reason of the velocity of the Illinois river, the momentum of the particles delivered into the Mississippi would be such as to carry them out into the stream, in fact, it is observed that when the Illinois river is in flood the waters pass well out into the main stream of the Mississippi river. The distribution of velocities and distribution of pressures has much to do with the mixing. The swifter flowing water transmits less pressure to the water adjacent to it, and consequently the Illinois river entering the Mississippi at a lower velocity than the Mississippi is flowing, the waters of the Illinois would be drawn, or forced, to mingle with the Mississippi river, just as we are enabled to pump water by means of the jet pump where we deliver a jet of water through a channel at a high velocity, and that entrains with it slower moving water at its side and carries it out of the place where it originally was. In other words, to express it in more popular language, the swifter moving stream exerts a suction upon the water of the slower moving stream which leads to the dissemination and mixing of the latter through the former. (Williams, Vol. 3, pp. 2434, 2435.)

15.

MOST CONCLUSIVE EVIDENCE OF THE SANITARY QUALITY OF THE WATER SUPPLY.

The best criterion of the sanitary quality of the water supply that is being used by a community for domestic purposes is the presence or absence of water borne diseases among the sources

of the supply, and especial reference and consideration may be given to typhoid fever, as it is at present the most important of the water borne diseases.

(Williams' testimony, Vol. 3, pp. 2462-3-4-5-6-7.)

The fact that the chemical analysis of water fails to show the presence of disease producing infection is no evidence to an expert that no such infection may exist in the water.

(Williams' testimony, Vol. 3, pp. 2462-3.)

The reason given for the failure of chemical analysis to disclose disease producing organisms which are recognized as being contained in polluted water is that the infectious quality of the water is not dependent upon its chemical constituents, but upon the presence of the living organisms themselves, which are of such minute character that they pass entirely beyond the range of chemical analysis to detect, and yet are contained in the water in sufficient quantities to cause very serious results in the event the water be used for drinking and domestic purposes. What is true with reference to the chemical analysis may also be applied to the science of bacteriology. Such minute quantities of the water are examined as compared with the entire volume used that bacteriology fails in its application to disclose disease producing bacteria, although they may be scattered about in the water in variable quantities. This fact was excellently brought out by a series of analyses made of the River Dee, in Scotland, whereby a series of analyses simultaneously made showed the bacteria contained in the water to be thousands in a cubic centimetre of water, while the chemical analysis was entirely unable to detect the presence of the added microbes: so in the waters of the Detroit river, chemists, in their analysis of the water, expressed themselves as entirely unable to detect any evidence of pollution, while the records of the city showed at the same time a tremendous epidemic of typhoid fever due to the water, which was being analyzed. It is, however, essential that whenever chemical, microscopical and bacteriological analyses of the water indicate the presence of substances which are known to be related to infectious matter, to

give the evidence of these analyses great weight in estimating the quality of the water, and an expert should not recommend such water for use until he becomes satisfied that the source of the organisms so found by him in the water which constituted the impurities are such as to be unlikely to affect the sanitary quality of the water. On the other hand, it is not necessary for the expert to depend or require either a chemical or microscopical or bacteriological analysis of water to determine its pollution.

It may also be said that while the bacilli coli communis is an important index to sewage pollution, the fact that they are not constantly found in every sample examined is not positive assurance that the water has become more suitable in character and less liable to infection.

(Williams' testimony, Vol. 3, pp. 2464-5-6-7.)

16.

THE EFFECT OF THE OPENING OF THE CANAL IN CHICAGO UPON THE ST. LOUIS WATER SUPPLY.

The population of the city of Chicago, according to the census of 1900, was 1,650,000.

The population of the State of Illinois in the vicinity of Chicago, which also discharges its sewerage in the Chicago Drainage Canal above Lockport, at which point the controlling works of the Chicago Drainage Canal is situated, is roughly estimated at 350,000. It is a conservative statement to say at this time the sewerage from a population of 2,000,000 is discharged into the canal and thence into the Des Plaines and Illinois river.

(Dr. Ravold's testimony, printed record, volume 1, page 767.)

The waste of 2,000,000 people is emptied into the Drainage Canal above Lockport, twenty-seven miles from the city of Chicago proper. There is about three ounces of excrementitious matter and forty ounces of urine per day of twenty-four hours in the sewerage of a city, for each person residing in it. This

would represent about 190 tons per day of solid excrementitious matter and about 670,000 gallons of urine discharged into the canal at Chicago each day of twenty-four hours. The water consumption per day at Chicago is something like 360,000,000 gallons per day for the entire population. This, together with the natural discharges, represents the combined sewerage discharge of the Sanitary District of Chicago per day. The maximum discharge of water through the Canal into the Des Plaines river is 300,000 cubic feet per minute, which when mixed with the sewerage of Chicago represents a dilution of one to nine, or one part sewerage to nine parts Lake Michigan water. With this dilution it is readily seen by a perusal of the bacteriological results obtained from samples collected at Lockport that the diluted sewerage does not approach in the slightest degree a resemblance to a sanitary water.

(Dr. Ravold's testimony, printed record, volume 1, pages 769-770.)

At times dead fish were seen floating over the Bear Trap Dam from the Canal. In November, 1900, as many as 500 were observed to pass over in a period of ten minutes.

(Dr. Ravold's testimony, printed record, volume 1, page 770.)

The Des Plaines river at Joliet, exclusive of the water added to it by the Chicago Drainage Canal, is a very small stream, as is also the Illinois river at its source.

The population, urban and rural, of the Illinois river basin, exclusive of Chicago and the Sanitary District of Chicago, is stated by Dr. Ravold at 1,305,503. While the population of the Sanitary District of Chicago is about 2,000,000 or 45,000 more than the entire population residing in the natural basin of the Illinois river.

(Dr. Ravold's testimony, printed record, volume 1, pages 775-776.)

The average number of deaths from typhoid fever per annum at Chicago for some years past has been about 560, which

represents more than 8500 cases per year. By the opening of the canal the waters of the Illinois river have become subjected to and infected with the typhoid bacilli of this large number of patients. More striking does this appear and more certain is its effect on the waters of the Illinois and Mississippi river when we take into consideration the fact that typhoid bacteria to the number of 172,000,000 per cubic centimeter are found in the urine of a person sick of the disease.

(Dr. Ravold's testimony, printed record, volume 1, page 789.)

From the foregoing statement it is not surprising that the following bacterial results were obtained by Dr. Ravold in his examination of the waters of the Illinois river after the Drainage Canal had been opened. After setting forth tables showing the number of bacteria per cubic centimeter found in the respective waters for the respective times, Dr. Ravold stated that the bacilli were highest in the Canal at Lockport from the 17th to the 23rd of November, 1900, and that they were still high on the 25th of November at points below Lockport.

At Peoria there was a rapid rise immediately following the 17th of November, Peoria being 125 miles below Chicago. This rise at Peoria corresponds with the rise and fall of bacilli at Bear Trap Dam, Rubey street and Brandon's Bridge at Joliet during this same period.

During this period the stage of the river remained remarkably even throughout, and the bacteria was some higher, and the water was a little bit lower than it had been the previous weeks.

(Printed record, volume 1, pages 450-459.)

It indicates therefore that a large number of bacteria put in the Chicago river came through to Peoria.

(Printed record, volume 1, page 459.)

At Grafton, 163 miles below Peoria, during the month of November, 1901, there was an apparent increase in bacteria. Corresponding with the increase during the same period or im-

mediately before, at Peoria and Lockport, the number of bacteria at the high points during the month at Grafton is 34,000. The river was lower at that time than it had previously been.

(Printed record, volume 1, pages 460-462.)

A comparison of the bacterial counts of the waters contained in the Illinois river prior to the opening of the canal with those obtained since the opening sufficiently demonstrates that the water of that river is more highly polluted since the opening of the canal than prior thereto, and this, too, regardless of the fact that from 250,000 to 300,000 cubic feet of water per minute from Lake Michigan is being continuously added to the force and volume of water flowing down into the Illinois river.

Dr. Ravold in his testimony, with reference to the condition of the water in the Illinois river and its effect upon the Mississippi river water immediately after the opening of the Drainage Canal, stated as follows:

"Our work upon the rivers indicated, and we are pretty confident about that, that the first discharge of the Chicago river through the Drainage Canal at the opening which occurred on the 16th or 17th of January, 1900, reached here by the 29th or 30th of January, and passed, at which time, fortunately for St. Louis, the Missouri river was very high. At that time I thought over the question as the source of this pollution and looked over the samples microscopically, and my conclusion was this, if you care to hear it. This mass of filth that was in the Chicago river and in the Drainage Canal while it was retained there, after the waters of the Drainage Canal were allowed to stand or the waters of the Chicago river were allowed to stand in the Drainage Canal for a time without being discharged. The opening of the canal discharged the water over the dam and it came rushing down the Illinois valley and traces of it could be seen with the unaided eye for a great distance, as the water traveled along. The Illinois river was not high at that time. The great part of the solid suspended matter was carried down, making a black nasty mud in the stream. It was also winter time and the an-

aerobic bacteria were not at work, consequently they had not destroyed the organic sediment.

(Dr. Ravold's testimony, printed record, volume 1, pages 839-840.)

(Keiser's testimony, pages 988-989.)

On cross-examination Mr. Springer asked the following question:

Then so far as your analysis is concerned, you charged up all the impurities that you found at Grafton to the Drainage Canal?

To which Professor Keiser answered as follows:

Well, in this way, as we ascended the river and we found the impurities steadily increasing, as we went up the river. I reasoned that if the impurities came slightly from the tributaries of the river, the quantity of free ammonia and albuminoid ammonia and nitrites would be pretty constant on the way up the river and up through the tributaries if the waters were homogeneous, they would show that on analysis, but we found a very great increase all the way to Joliet, at which point the analysis shows the water to be diluted sewage.

The increase in impurities consisted of free ammonia, nitrites, chlorine and albuminoid ammonia.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1109-1110.)

The average amount of chlorine found in the Mississippi river above Grafton is from four to five parts per million. Immediately below Grafton, after it has received the waters of the Illinois river, the quantity of chlorine is increased from 4 to 16 parts per million. So that from the chemical standpoint it will be readily observed that the Illinois river contributed largely to the increase of chlorine in the water of the Mississippi river.

(Prof. Keiser's testimony, printed record, Volume 2, page 1110.)

Cross-examination of Prof. Keiser, Volume 2, pages 1127-1148.)

According to the chemical observations made by Professor Teichmann of the water of the Mississippi river and the Illinois river above Grafton, as shown by table No. 1 of Professor Teichmann's testimony, the following general average results were obtained for the year 1899, estimated in parts per million, total residue on evaporation:

Illinois river above Grafton, average..... 413
Mississippi river above Grafton average..... 340

Samples from which the foregoing average results were obtained were collected between September 6, 1899, and January 6, 1900, near the mouth of the Illinois river.

NITROGEN AS AMMONIA.

Illinois river above Grafton, general average..... .215
Mississippi river above Grafton..... .069

ALBUMINOID AMMONIA.

Illinois river above Grafton..... .317
Mississippi river above Grafton..... .314

NITROGEN AS NITRITES.

Illinois river above Grafton..... .012
Mississippi river above Grafton..... .002

NITRATES.

Illinois river above Grafton..... .8
Mississippi river above Grafton..... .3

Samples from which the foregoing average results were obtained were collected between September 6, 1899, and January 6, 1900, near the mouth of the Illinois river.

(Prof. Teichmann's testimony, printed record, Volume 2, page 1177.)

From October 16, 1899, to January 22, 1900, free ammonia samples were collected at the Intake, Chain of Rocks. The

average results of the examination, expressed in parts per million, were as follows:

Nitrogen as free ammonia	.0063
Nitrogen as Nitrites	.002
Nitrogen as Nitrates	.4
Nitrogen as Chlorine	.17

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1180-1181.)

A comparison of these results with results obtained since the opening of the Drainage Canal show that the Mississippi river has retained its condition of stability since the opening of the canal, while the Illinois river above Grafton and the Mississippi river below Grafton have experienced a great increase in polluting and contaminating constituents.

The testimony of Dr. Teichmann is based upon his personal analysis and observation of a large number of samples of water collected from the following named points:

Lake Michigan.
Drainage Canal above Bear Trap Dam at Lockport.
Des Plaines river at Joliet.
Illinois river three miles above Peoria.
Illinois river at Wesley immediately below Peoria.
Illinois river at Pekin bridge.
Illinois river three miles below Pekin.
Illinois river three miles above Grafton.
Mississippi river two miles above Grafton.
Mississippi river one mile above Alton.
Mississippi river opposite Hartford.
Missouri river opposite Fort Bellefontaine.
Mississippi river near Missouri shore, Chain of Rocks.
Mississippi river near Illinois shore, Chain of Rocks.
Mississippi river at Chain of Rocks.
Intake Tower.
The Wet Well of St. Louis Waterworks.
Outlet reservoir, St. Louis Waterworks.
Tap at City Chemist's office, St. Louis.

During the period of the investigation, samples were collected daily, which were analyzed and from which weekly, monthly and periodically averages were determined and expressed.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1182-1183.)

An examination of the chart and exhibits read in evidence by Dr. Teichmann show the result of the chemical analysis of water of the respective rivers after the opening of the Drainage Canal.

Immediately after the opening of the canal the Illinois river below Joliet became very much increased in polluting material. The results clearly show an enormous pollution caused by flushing out the Chicago river and the canal. The amounts of free ammonia, chlorine and nitrites represents the effect produced. It will be observed that in January, immediately after the opening of the canal, chlorine ran up from 21 to 28 parts per million at Peoria. This is followed by an increase at Grafton from 15 to 23 parts per million. Chlorine running very much together in their fluctuations at Peoria and at Grafton.

In regard to free ammonia, it will be noticed that the condition three miles above Grafton is caused by large quantities of free ammonia three miles above Peoria. Thus following the opening of the Drainage Canal, we find a great raise in the free ammonia at Peoria and afterwards a corresponding raise at Grafton, and as this decreased at Peoria it is found to decrease at Grafton.

The action of nitrites in the water corresponds with that of free ammonia, thus high nitrites in the Illinois river above Peoria is afterwards followed by high nitrites above Grafton.

As to the stability of the respective waters, it will be observed from these analyses that nitrites raise and fall in the Illinois river above Grafton, and show much higher in results than the Mississippi river above Grafton.

Chlorines are much lower in the Mississippi river during the entire year. In fact all of the chemical constituents abruptly

change in the Illinois river, while they remain at a permanent stage in the Mississippi river.

The Illinois river at Grafton is shown to be in a fermentative state, the process of purification not having been completed as shown by high nitrites, free ammonia and nitrates. While the stability of the waters in the Mississippi river is shown by low nitrites, free ammonia and chlorine, which run practically the same throughout the entire period.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1198-1212.)

From the chemical analyses made with the water of the Illinois river by Professor Teichmann, it will be observed that the water of that river, after the opening of the Canal, was unable to completely recover itself within the time required for the water to flow from Chicago to St. Louis.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1215-1216.)

For the week beginning January 30th, the average result of free ammonia in the Illinois river at Grafton amounted to 1.675 parts per million, while in the Mississippi river, a few miles above the mouth of the Illinois, the corresponding average was .175, which is only one-tenth of the free ammonia that was found in the Illinois river above its mouth.

At Alton and Hartford free ammonia was found, average 1.055 and .865 parts per million respectively.

So it will be observed that there was a remarkable increase in free ammonia in the Mississippi river after it had received the waters of the Illinois river.

What is true with reference to free ammonia holds good as to nitrites, nitrates and chlorine.

An observation of the examination of the Missouri river water shows less contamination than in the Mississippi river, so that the unquestionable conclusion must be accepted that a

large percentage of the polluted material found in the water supply of the city of St. Louis comes from the Illinois river.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1222-1223-1224-1225 and 1245.)

The water of the Mississippi entering into the intake during the period from 1895 to 1899, inclusive, was more safe from a sanitary standpoint after it had been settled in settling basins and delivered to the consumers than it is today. From an examination of the typhoid statistics of St. Louis during the period from 1895 to the end of the year 1902, which show that in 1895 there were 106 deaths, in 1896, 107 deaths; in 1897, 125 deaths; in 1898, 95 deaths; in 1899, 130 deaths; in 1900, 168 deaths; in 1901, 197 deaths, and in 1902, 222 deaths, it will be found that the average number of deaths in the five years from 1895 to 1899, inclusive, was 112 per annum, while the average annual deaths for the three years beginning with January, 1900, was 196, showing an increase in round numbers of about 80 per cent.

Taking into consideration the differences in population, that is the increase in population during that period, and expressing the typhoid fever deaths with reference to the number per hundred thousand of population living, there has been an increase during the past three years on an average of about 77 per cent over the annual typhoid death rate per one hundred thousand population living for the five years, 1895 to 1899, inclusive.

Comparing the number of deaths from typhoid fever during these eight years, with reference to the total number of deaths from all causes occurring in the city of St. Louis, and obtaining the percentage of mortality from typhoid fever, the percentage of increase for the last three years on an average as compared with the average percentage of mortality from typhoid fever during the preceding five years is 73 per cent. The average number of deaths from typhoid fever in St. Louis during the past five years under consideration was about 20.4 per hundred thousand population, and at this rate during the past three years, on an average, was about 32.3 on the same basis per hundred thousand population, so that it will be observed from this standpoint that the St. Louis water supply cannot be

classed as a good water, and must be considered as having become more infected with disease producing organisms than prior to the opening of the canal, the manner of treatment during the entire period being essentially the same.

(See Fuller's testimony, Vol. 3, pp. 2610 and 2615.)

After familiarizing himself with typhoid fever statistics in the larger centers of population of the Mississippi river watershed above the Chain of Rocks, excluding the Sanitary District of Chicago, during the period from 1895 to 1902, inclusive, Mr. Fuller made the following remarks:

"During these periods there have been at quite a number of points, some variations in the amount of typhoid fever prevailing in different years. Taking the typhoid fever statistics upon this watershed area as stated, as a whole, but excluding the Sanitary District of Chicago, based upon the average number of deaths from typhoid fever per year, it is my judgment, viewing the matter as a general proposition, that there has not occurred on the natural area of the Mississippi watershed above St. Louis any increase in the number of deaths sufficient to explain to any material degree the less safe condition of the Mississippi river water as taken from the intake tower of the St. Louis waterworks, during the last period, as compared with the period 1895 to 1899.

"In my judgment, the Chicago Drainage Canal renders the water of St. Louis less safe than it was prior to January, 1900." (See Fuller's testimony, Vol. 3, p. 2613 to 2620, inclusive; Hazen's testimony, Vol. 3, page 2838.)

The effect of the water of the Mississippi river upon the people of St. Louis immediately ofter the opening of the Chicago Drainage Canal will be readily appreciated when the typhoid mortality of the city is examined and compared with previous periods. The canal was opened January 17, 1900, and allowing time for the passage of the water from Chicago to St. Louis, time for the incubation of the germ in the patient and the average time for sickness and death, it is observable that an increase of 1,300 per cent in deaths took place in March, 1900,

over conditions existing during the same month in the years 1895-6-7-8-9, respectively.

(See Teichmann's testimony, Vol. 2, pp. 1241-2.)

The typhoid conditions in St. Louis, after the opening of the drainage canal is a very striking demonstration of the increase of the pollution of our water supply had from the polluting effect of the waters of the Drainage Canal and the waters of the Des Plaines and Illinois rivers upon the Mississippi river. It is apparent that there is a striking correspondence in the increase in pollution in the river during the month of March, 1900, with an increase of typhoid in February of 1,300 per cent over the average for that month for the five preceding years, the typhoid results for the month of March, 1900, becoming almost epidemic, and immediately following the pollution of the water supply traced to Grafton, thence to the Des Plaines, and thence to the Chicago Drainage Canal. The effect of the opening of the canal was followed by a pollution higher than was ever before experienced in the history of the city of St. Louis, and this pollution, highly contaminated as it was with typhoid bacilli, did not escape the intake tower and the St. Louis water supply, as evidenced by the large number of deaths and cases from typhoid fever in the city immediately following.

(Teichmann's testimony, Vol. 2, pp. 1445-6.)

Prof. Sedgwick stated that he had made a very careful study of the typhoid fever statistics of the city of St. Louis, and of the physical surroundings conducive thereto. During the period of fifteen years prior to January 1, 1900, the typhoid death rate in St. Louis was not above that of some cities provided with water supplies considered poor. During the period following the removal of the intake from Bissell's Point to the Chain of Rocks the typhoid death rate of St. Louis was remarkably good, lower than it had been for some time, and lower than the death rate for the city of Boston for the same period. Beginning with the first day of January, 1900, there has been a remarkable annual increase in the typhoid death rate of the city of St. Louis, so that during the last period it has not only been higher than

during the previous five years, but has been higher than at any time in its own history since 1885, excepting during the epidemic of 1892, and very much higher than the death rate in the city of Boston, with which it previously compared very favorably. The increase in typhoid fever deaths in St. Louis since January 1, 1900, as compared with the preceding fifteen years, has been 26 per cent, while the increase since January 1, 1900, in the annual mortality as compared with the preceding five years has been 73 per cent. The water supply of Boston is considered fairly good, and the typhoid rate of that city has been and is below that of most cities of a similar size. Boston and St. Louis, prior to January 1, 1900, have run very close together so far as typhoid deaths are concerned, but since January 1, 1900, Boston has gone lower and St. Louis has increased.

(See Sedgwick's testimony, Vol. 3, pp. 2203-4-5, and 2239, 2250-1.)

At Vol. 3, page 2214, Prof. Sedgwick made the following statement:

"After a careful consideration of the subject I can say that in my opinion, beyond a reasonable doubt, the principal portion of the annual increase of typhoid fever in St. Louis since January 1, 1900, has been due to the pollution of the water supply of St. Louis by the sewage of the Sanitary District of Chicago."

On cross-examination counsel for respondent undertook to and did qualify the witness as to what was his understanding of the term "beyond a reasonable doubt," as used by him in the above answer. Prof. Sedgwick had evidently given a careful study to the essentials in determining the source of infection as applied to the science of epidemiology, and in his experience had doubtless been led to accept only such evidence and to apply only such rules as would unquestionably lead to a discovery of the truth. In answer to the question propounded by counsel for the defendant, "What is a reasonable doubt," Prof. Sedgwick said:

"I have no objection to telling what I understand by the expression, 'beyond a reasonable doubt.' I mean by that an assurance of accuracy such as shall persuade me to the truth."

"Q. Do you understand that a reasonable doubt is one that must arise solely from the evidence adduced, and which excludes every other reasonable hypothesis from that of guilt?

"A. As I understand the question, that is my understanding of the conditions required."

(See Vol. 3, pp. 2214 and 2306; also, 2292-3-4-5-6, 2358, 2381 and 2394.)

Gardner Williams, in speaking of the effect of the sewage of Chicago upon typhoid conditions in St. Louis, made this statement:

"I should say that the evidence afforded by the typhoid statistics of St. Louis for the period of 1895 to 1899, inclusive, was not ideal, but, nevertheless, would compare favorably with that of a large number of our American cities, and that, generally speaking, it would entitle the St. Louis water supply to rank in about the second class of water supply, as experts generally speak of them. Considering the evidence of the typhoid statistics of the city of St. Louis since the beginning of 1900, it appears that up to near the end of January the water supply of St. Louis during that month must have been about as good as formerly, but about that time there appears to have been a considerable infection of the supply, which has increased since each month, with the results that the typhoid statistics show the probable infection of the supply during 1900 to have been twice as great as the average between 1895 to 1899, inclusive, and that the rank of the water supply of St. Louis has materially dropped, as judged by the standard of sanitary purity. I have examined the records of typhoid fever in the cities on the Mississippi, Illinois and Missouri rivers, outside of the Sanitary District of Chicago. The Drainage Canal was opened on January 17, 1900. Basing my judgment upon the facts brought to light, the extensive examination of the conditions, it is my judgment that to the discharge of sewage by the Sanitary District of Chicago

by means of the Drainage Canal, the Des Plaines and the Illinois rivers, is attributable the major part of the increase of the typhoid fever as arrived at by the typhoid statistics of St. Louis since January 1, 1900, as compared with the period from 1895 to 1899, inclusive."

(See Williams' testimony, Vol. 3, pp. 2462-3.)

The testimony shows that since the opening of the Chicago Drainage Canal the water flowing into the Intake of the St. Louis Waterworks is unsuitable for domestic purposes, while prior to the opening of the drainage canal it was considered fairly good water, in fact, based upon the mortality record it may be said to have been a reasonably good water supply, while based upon the mortality record since the opening of the drainage canal as compared with conditions existing prior thereto, and as compared with the mortality records of various other cities of similar size, it must now be classed as unwholesome water.

(See Teichmann's testimony, Vol. 2, pp. 1242-3-4-5-6.)

Based upon the analytical results it is shown that the water entering the intake in 1900 was more polluted than the water entering the intake in 1899, and that since there was no corresponding increased pollution in the Mississippi river above the mouth of the Illinois and no increase in the pollution of the Missouri river above its mouth, it must be taken as true that the increased pollution of the water going into the Intake tower was caused by and due to the increased pollution of the Illinois river in 1900 and since. It is also true that there was no real or substantial change in the physical condition of the Illinois river watershed during the period from 1899 to the present time save and except as to the addition of the sewage of the city of Chicago through and by means of the Chicago Drainage Canal.

(Teichmann's testimony, Vol. 2, p. 1245; Williams' testimony, Vol. 3, p. 2437.)

17.

LONGEVITY OF BACILLUS TYPHOSUS OR TYPHOID BACILLI.

Since the discovery of Bacillus Typhosus as the cause of typhoid fever, professional investigators and sanitary scientists have employed every known and conceivable means of determining the exact duration of the life of this particular microorganism. After the most extensive and careful investigation it is yet unknown just how long the germ may live under the various conditions in nature. Sufficient information, however, has been obtained to know that much depends upon the resisting powers and individual strength of each particular bacillus.

It is pertinent to the issues in this case to know just how long it will be in the water of the Chicago Drainage Canal, the Illinois and Mississippi rivers. This is, according to all of the witnesses who testified in the case, after many series of determinations, a matter yet unknown. However, judging from the length of the life of the germ in laboratory experiments, we are able to reach a minimum limit of approximation, but under no circumstances can we reach the maximum limit. This depends largely upon the resisting force of the germ, its vital powers and the condition of the water into which it is discharged.

Dr. Ravold in this connection made some very valuable experiments as to the life of the germ in the sterilized, the distilled, and the natural waters of the rivers in question.

These experiments were made continuously from June to September, 1902. During which period work was constantly and continuously done for the purpose of determining sufficient information and knowledge upon which to base a definite conclusion as to its longevity in these waters. The examinations were made under almost every conceivable manner practicable in laboratory work.

In the unsterilized living water of the Mississippi river at St. Louis he found the germ would live from eight to twenty-one days. In sterilized water (boiled to such temperature as

was sufficient to kill all germ life contained in it) it was found that the germ of this disease lived from twenty-five to sixty days.

The foregoing experiments were made with the samples of water containing the bacilli typhosus, suspended in an open window exposed to the sunlight during the entire day. Similar experiments were made with the samples of water enclosed in total darkness, with results practically the same.

(Dr. Ravold's testimony, printed record, Volume 1, page 49.)

During the period above mentioned, the following results in sterilized, distilled and natural water were obtained by Dr. Ravold in his experiments as to the longevity of this particular micro-organism.

The Mississippi river at Grafton, in total darkness, 10 degrees Centigrade or fifty degrees Fahrenheit, it lived 59 days.

First culture 40 days, C culture and B culture not recorded.

The testimony of Dr. Ravold shows that these experiments were made with three cultures, known as A, B and C.

Again under similar circumstances A culture was found to live 51 days, B culture 25 days and C culture 22 days.

In sterilized water, taken from the Chicago Drainage Canal at Lockport, kept in total darkness, at ten degrees Centigrade or fifty degrees Fahrenheit, this bacillus lived

A culture 45 days, B culture not recorded, C culture 22 days.

In sterilized water of the Missouri river, collected at Fort Bellefontaine, kept in total darkness at ten degrees Centigrade or fifty degrees Fahrenheit,

A culture lived 59 days, B culture 57 days and C culture 57 days.

In sterilized Mississippi river water collected at the Intake, Chain of Rocks, St. Louis Water Works, kept in total darkness, at ten degrees Centigrade or fifty degrees Fahrenheit,

A culture lived 59 days, B culture 59 days and C culture 34 days.

IN DISTILLED WATER.

Kept in total darkness at 20 degrees Centigrade or sixty-eight degrees Fahrenheit,

A culture lived 22 days, B culture 54 days and C culture 30 days.

Distilled Mississippi river water collected above Grafton, kept in total darkness at 20 degrees Centigrade or 68 degrees Fahrenheit,

A culture not recorded, C culture not recorded, and B culture lived 37 days.

In distilled water collected from the Drainage Canal at Lockport, Illinois, kept in total darkness at twenty degrees Centigrade or sixty-eight degrees Fahrenheit,

A culture lived 54 days and B culture lived 54 days.

In distilled Missouri river water collected at Fort Bellefontaine, kept in total darkness, at twenty degrees Centigrade or sixty-eight degrees Fahrenheit,

A culture lived 57 days, the other two cultures not being recorded.

In distilled Mississippi river water collected at the Intake of the St. Louis water supply, kept in total darkness at twenty degrees Centigrade or sixty-eight degrees Fahrenheit,

A culture lived 54 days, B culture 55 days and C culture 54 days.

Distilled water kept in the open window, facing the east with the sun shining upon it the entire forenoon of each day, with 100 Cubic Centimeters of water contained in the bottle,

A culture lived 22 days, B culture 22 days and C culture 45 days.

These experiments taking place in July, August and September of 1900.

The following, under similar conditions, of water collected from the Mississippi river above Grafton,

B culture lived 45 days, C culture 60 days.

Distilled water taken from the Drainage Canal at Lockport,

A culture lived 40 days, B culture lived 31 days and C culture lived 22 days.

Mississippi river water, Intake Tower,

B culture lived 46 days, C culture 45 days, A culture still living at the end of 65 days.

A series of experiments were conducted by Dr. Ravold in June, July and August, 1901, for the purpose of determining the length of the life of the bacilli typhosus, in the samples of living water from the Chicago river, Chicago Drainage Canal at Lockport, Illinois, the Illinois river at Peoria, and the Mississippi river at the Intake.

Samples of water were collected at different times from the above named points and 200 cubic centimeters poured into sterilized Erlemeyer flasks and corked with cotton stoppers. Some were exposed to the sunlight, others kept in darkness at a temperature of 16 degrees Centigrade or 60.8 Fahrenheit. Those exposed to sunlight were placed on a shelf in a window, facing south, and the direct rays of the sun impinged full upon the western flask in the window at 10:45 a. m., and left the flask furtherest east at 2:15. The total time of exposures to the sunlight daily being about three hours. The samples of all water used in conducting these experiments being turbid.

A record was kept showing the hours of sunlight on the respective days during which the determinations were made, together with a record of the temperature of the atmosphere in the window where the samples were kept.

(Dr. Ravold's testimony, printed record, Volume 1, page 472.)

The typhoid culture used in these experiments were,

No. 1 received from Dr. Westbrook of the University of Minnesota, said to be found by him in the waters of the Mississippi river at Minneapolis.

No. 2 came from the spleen, sent in by Dr. C. G. Kirchner from a patient dead of typhoid fever at the City Hospital, St. Louis, and separated out in the laboratory June 8th, 1902.

It will be noticed that the result of the two cultures are practically the same.

In the window the following results were obtained:

Water collected from the Drainage Canal, Western Avenue, Chicago, June 13th, typhoid bacilli lived five days.

Water collected July 15th, 7 days.

In water collected from the Drainage Canal at Lockport, June 13th, typhoid bacilli lived 4 days.

July 5th, 8 days.

In samples of water collected from the Illinois river above Peoria, June 13th, typhoid bacilli lived 5 days.

July 5th, 10 days.

July 11th, 8 days.

Water collected from Illinois river, Pekin Bridge, June 13th, typhoid bacilli lived 4 days.

June 5th, 10 days.

Water collected from Chicago river, Adams street, June 13th, typhoid bacilli lived 4 days.

In the laboratory the following results were obtained: From water collected from Chicago river, Adams street. On the 16th day the bacillus was still alive.

Water collected from Chicago Drainage Canal, Western Avenue, at 16 degrees Centigrade, typhoid bacilli lived 7 days.

July 5th, 8 days.

Water collected from Drainage Canal, Lockport, July 15th, 10 days.

Water collected from Drainage Canal above controlling works, Lockport, June 13th, lived 9 days.

Illinois river above Peoria, June 13th, lived 10 days.

July 5th, 21 days.

July 17th, 16 days.

Chicago river, Adams street, June 13th, this bacillus lived 4 days.

July 5th, 7 days.

Tap in the laboratory in St. Louis, June 13th, lived 12 days.

Chicago river, Adams street, July 5th, lived 23 days.

Drainage Canal at Lockport, July 17th, lived 11 days.

Drainage Canal, Jackson street, Joliet, July 17th, lived 13 days.

Illinois river, Pekin Bridge, July 17th, lived 16 days.

Dr. Ravold in this connection showed that with reference to experiments in the sunlight typhoid bacillus lived on an average of five days in natural water collected from the Illinois and Michigan Canal at Lockport.

In water collected from the Drainage Canal, Western Avenue, Chicago, the average life in the window was six days, in the refrigerator 7½ days.

In water collected from the Drainage Canal at Lockport the average life of this bacillus in the window was 4¾ days, in the refrigerator 10 2-3 days.

In water collected from the Drainage Canal, above the controlling works, Lockport, the average number of days in the refrigerator was 9.

From samples of water collected from the Drainage Canal, Jackson street, Joliet, the average number of days alive in the window was 9, in the refrigerator was 13.

From samples of water collected from the Illinois river above Peoria, the average number of days alive in the window was 7 2-3 days, in the refrigerator 11½ days.

From samples of water collected from Illinois river at Pekin the average number of days alive in the window was 7, the average number in the refrigerator 15.

From samples of water collected from the Chicago river at Adams street, the average life of this germ in the window was 4 days, in the refrigerator 5½ days.

In water collected from the tap in the laboratory, St. Louis, the average life in the window was 7 days, in the refrigerator 12 days.

(Dr. Ravold's testimony, printed record, Volume 1, pages 468-476, inc.)

The testimony of Dr. Ravold on the longevity of the typhoid micro-organism is substantially as follows:

It is impossible to carry out in a laboratory experiment the condition which obtain in a running stream. In living water in a flask in the laboratory experiment the bacteria are in evidence, each of which produces a particular toxin, so that in a very short time the toxines produced by the micro-organisms that are at work seem to act unfavorably upon the typhoid bacillus placed in the water. In sterilized water the typhoid lived quite a number of days longer than in the natural water.

In a running stream the typhoid micro-organism is not subjected to the poison produced by other bacteria to the same extent as in the stagnant water in the flask. In the running stream it would not be confined to a given water, because it can swim about and be carried along by the running water. Its chances in living, running water would, therefore, be vastly greater than in the flasks.

The micro-organism is not known to multiply in the water of a river into which it is discharged. It remains dormant until its life history is over, unless in the meanwhile it reaches a favorable condition for growth and multiplication.

It is not known that the death of the typhoid bacillus is due to the toxins produced by the bacteriological conditions of its life and the causes of its death in running water are not definitely known. In fact, it is impossible under the science of bacteriology, as it exists today, to definitely ascertain its longevity in the various conditions of nature in which it is known to exist.

Dr. Ravold's testimony, printed record, Volume 1, pages 478-479-480.)

It is impossible to determine the absolute longevity of typhoid bacillus in running water, because the conditions which obtain in a stream cannot be produced in the laboratory experiments, and to put living typhoid bacilli in water that is used for drinking purposes would be murder. So, therefore, no experiment can be made in a living stream. The conditions in the water are these: The toxins or product produced by water bacteria that may or may not be deleterious to the typhoid bacillus would be greatly diluted by the flowing water. Typhoid bacillus is a mover, and can swim out of the way of any thing that would be deleterious to it in a river. The fact that it is motile is the reason it can exist in the water of a river highly charged with sewerage. It has motility and can move away from the deleterious products or substances contained in the water. In laboratory experiments it is confined and therefore unable to prolong its life.

(Dr. Ravold's testimony, printed record, Volume 1, pages 790-791-792.)

It was scientifically determined by the Massachusetts State Board of Health that a typhoid bacillus lives in the waters of the Merrimac river for twenty-five days. These experiments were made at Lawrence and Lowell, Massachusetts.

(Dr. Ravold's testimony, printed record, Volume 1, page 50.)

It is not affected by freezing and will, therefore, live in ice. If discharged into the Illinois and Mississippi rivers and those rivers should, within the life of the germ, become frozen over with ice, the germs contained in the ice would not be thereby destroyed, but would live in a dormant condition until the ice disappeared and then until they had run their natural time or duration of life.

The sunlight has some effect on them, it shortens their life to a limited extent. However, as a general proposition, the belief among some that they are entirely killed by the sunlight is now known to be a myth; it is not true.

In a stream they naturally seek the darker regions of the water, and for that reason are affected by the light to a very slight extent. The sunlight would not affect them to a greater depth than one foot in the Illinois river. The result is they would descend to and travel in the more rapid portion of the stream.

(Dr. Ravold's testimony, printed record, Volume 1, pages 797-798-799.)

They have been known to exist in soil for a considerable time, and to be discharged from a person sick of the disease for a period of 8 to 18 years after recovery.

(Dr. Ravold's testimony, printed record, Volume 1, page 790.)

Dr. Ravold in this testimony further stated that typhoid bacilli would live for a long time in a moist earth, as a number of experiments have shown this to be true. Experiments by Firth and Horniks show that these micro-organisms live a long time in earth and sand that is moist and retain their virulency.

That it has been known to live 25 days in dry earth and longer than that in moist earth. The above named experts carried out a series of experiments and were able to capture the typhoid bacillus in the dust by blowing across the typhoid infected earth.

The dredging at Detroit, Michigan, show that the germ lived a great length of time in the mud and filth of lakes and rivers, and after being stirred up retain their virulence and spread the disease.

(Dr. Ravold's testimony, printed record, Volume 1, pages 953-954.)

Typhoid fever germs will live in sewage polluted waters, such as are found in streams, reservoirs and the like, for a period of weeks and months. (Fuller's testimony, Vol. 3, pp. 2617-18. Sedgwick's testimony, Vol. 3, p. 2314. Fuller's testimony on cross-examination, Vol. 3, pp. 2628-9. Fuller's cross-examination, Vol. 3, pp. 2664-5; also, Fuller's testimony, Vol. 3, pp. 2626-2627. Sedgwick's testimony, Vol. 3, pp. 2207 and 2765.)

Mr. Rudolph Hering, the defendants' witness, on cross-examination, was asked these questions:

"Q. Generally speaking, Mr. Hering, taking all the observations of bacteriologists and sanitary scientists the world over, what in your opinion is the longevity of pathogenic bacteria coming from the sewers of a city when discharged into a running stream?

"A. I consider that every disease bacterium has presumably a different length of life under the same conditions, and presumably also under the different conditions, and as I have not studied concerning any other bacteria than the typhoid bacillus I could not make such a general answer.

"Q. Mr. Hering, is there any instance in your whole career as a sanitary engineer, or an instance coming under your observation as to the work of other reputable sanitary engineers or sanitary scientists where the water in a running stream has been recommended as free from the typhoid bacilli of a large and populous city existing on that whatershed with a stream velocity of from ten to twenty days?

"A. Without filtration, I do not know of any case exactly answering your description."

Hiram F. Mills, for several years connected with the Massachusetts State Board of Health, conducted a series of observations as to the longevity of typhoid fever germs in the water of the Merrimac river. He found them to decrease rapidly in numbers from 1 to 25 days, and, based upon these determinations arrived at by Mr. Mills, Mr. Hering testified as follows:

"Q. The table prepared by you, or used by you, rather, giving the results of the experiments of Hiram F. Mills on the longevity of the typhoid germ is the one that you have heretofore used in your experiments and work as a sanitary engineer?

"A. Whenever I was called upon to consider the question of longevity of the typhoid bacillus I have had those Massachusetts experiments in mind." (Hering's testimony, Vol. 8, pp. 7026-7-9.)

In determining the longevity of typhoid fever germs, there is nothing in the sanitary science that permits an exact formula for the purpose of determining the life of the germ, so far as time limit is concerned, or, in other words, so far as the time required for the water to pass from the source of the deposit of the infected material to a given point in the stream. No such formula can be adopted, because it would not be wise or feasible in the present stage of sanitary science to attempt to advance the same, inasmuch as it contains certain elements which compel it to be considered as an individual case. The character of the specific microbe and the temperature of the water would certainly have to be considered and would certainly have some influence upon the period of longevity. The volume of water, the amount of dilution, the temperature of the atmosphere and the water would of necessity have to be considered. (Jordan's testimony, Vol. 7, pp. 6355-7-8.)

In reference to the experiments that have been made during the last fifteen or twenty years by different bacteriologists for the purpose of determining the data of longevity of typhoid bacilli, different methods have been used, and under these

various determinations the life of the typhoid bacillus has been reported to vary widely. They have been known to live in sterilized water taken from Lake Michigan as long as 93 days. It is, however, a well known and undisputed fact by bacteriologists and sanitarians that typhoid fever germs live in river water for a considerable period or length of time, varying upon the extent of the pollution, the character of the water, the temperature and the opportunities for sedimentation, and, therefore, there is a gradual dying-out in the bottom of the stream. Giving special resistant forces and the vitalizing powers of each individual germ, in his experiments conducted by the use of the parchment and celluodin sacs, Prof. Russell, in Vol. 7, p. 6512, found that in the waters of the Illinois river at Averyville, typhoid bacilli lived while contained in the sacs for a period of nine days. The following results are found to have been obtained:

On the third day 44 colonies were removed, of which 14 were found to be typhoid. These 44 colonies were taken from five sacs, and the typhoid organisms were found in three out of the five.

On the ninth day, two colonies were taken from two sacs, one colony of which proved to be typhoid.

So, with the limited number of experiments carried on by Prof. Russell, it will be observed that typhoid bacilli lived in this unnatural condition in the waters of the river at Averyville for a period of nine days. (See Russell's testimony, Vol. 6, pp. 6512-13.)

In this connection, we call attention to the fact that conditions in the parchment and cellodin sacs did not assimilate the actual conditions in the stream. This question was propounded to Prof. Sedgwick.

The following statements were made by Prof. Russell in his cross-examination:

"Q. Taking into consideration the care and precaution that was used by you in making the determinations contained in the tables which you read in advance, in your direct testimony, and assuming that typhoid fever dejecta is deposited in a running

stream which flows for a period of nine days, at which point the inhabitants of a city receive their water supply, and knowing that you had observed the presence of the typhoid bacilli during the series of examinations which you made in the water at that point—assuming the bacterial contents of that water to remain or be practically as contained in the sacs with which the observations were made, would you recommend that water as free from typhoid bacilli, and therefore suitable for domestic and drinking purposes?

"A. Taking into consideration the fact that typhoid organisms deposited in running streams would not be subject under natural conditions to such conditions as outlined in the foregoing question, for the reason that in such flow there are factors operative and always operative which are not assumed in the foregoing question, and which must be assumed if the conditions are made to refer to conditions that actually do obtain in a flowing stream, and taking into consideration all the knowledge which I possess from a bacteriological analysis of waters so exposed and the conditions which are referred to, it is my belief that waters discharged into a stream, the character of which corresponded to the conditions which are assumed in the question, but which under such conditions are affected by these other factors which are always operative, it is my opinion that typhoid organisms would not be found in such water when a period of flow was of nine days' duration.

"Q. But, assumming aside from the natural conditions that the water remained in the river as it remained in the sacs for nine consecutive days, and in the ninth day you found typhoid bacilli present, as shown in your observations, would you consider that water as being free from typhoid bacilli at the end of the ninth day?

"A. It would be impossible to base a recommendation of such a character unless all the facts which bear upon this question were taken into consideration, and if those facts were in accordance with the facts as represented in the experiment referred to in which analyses were made in large numbers and at daily intervals, and in which out of this series of analyses the typhoid organism was found abundantly the first day, the second and

the third day, but was not found at any subsequent date, although frequent daily examinations were made, except in one solitary instance, on the ninth day, and was found in no instance thereafter, although examinations were continued for double this length of time, I should under these circumstances consider that I was warranted in assuming that the typhoid organisms introduced in such water would have disappeared so completely that under no conditions would the water have been able to produce disease if it had been consumed by human beings.

"Q. And under the facts assumed, and at the end of the ninth day, you would recommend to the people that they could drink that water with impunity so far as the effects of the typhoid fever germs were concerned?

"A. The recommendation as to whether a water supply is pure or suitable for domestic use presupposes conditions which are not assumed in the foregoing question and which must of necessity be taken into consideration before any such recommendation can be made, and a water supply which is known to contain typhoid bacilli must, therefore, be subjected to exceedingly stringent examination before one would be warranted in making any such recommendation as indicated in the question.

"Q. Do you mean a stringent examination for the purpose of determining the presence or non-presence of typhoid bacilli?

"A. I do.

"Q. Do you consider the observations and examinations which you made of the water contained in the sacs, as shown in your tables, to be a stringent examination of that water, for the purpose of detecting the presence or non-presence of typhoid bacilli?

"A. I consider that the examinations which were made of the analysis of this water were sufficiently stringent to have detected the presence of the typhoid bacilli if such had been present.

"Q. Then under the conditions assumed in the preceding question that if the water in a running stream ran nine days was during the time in the same bacterial condition as the water contained in the sacs which were used in your experiments, and underwent the same bacterial changes, containing typhoid bacilli

which also underwent the same changes, that water would be suitable for drinking purposes at the end of the ninth day and at the place reached at the end of the ninth day?

"A. The conditions which were stated in the assumptions named in the question are so entirely foreign to what do exist when waters find their way in a flowing stream that a comparison which is made between the conditions of this experiment and the conditions which would occur when typhoid organisms were deposited in a running stream for nine days' flow, are such that I am unable to state exactly what would occur under the conditions assumed, but when I take into consideration the fact that in a case of water containing approximately 5,400,000 typhoid bacteria in a given volume, that an exposure of that water under the conditions as described in the foregoing answers failed to reveal the presence of typhoid organisms in all but one case out of the entire number examined on the ninth day, so that the vitality of this enormous number of organisms had been entirely lost with the exception of the single germ referred to, except in the case of the first three days, when typhoid organisms were demonstrated, I should consider that a conclusion which is based upon the results which were obtained in the case of this single organism alone and not the whole of the results of the experiment are not proper as indicating what the condition of affairs would be which would occur in nature." (Russel's testimony, Vol. 7, pp. 6600 to 6602, inclusive.)

Prof. Mason, one of the defendants' witnesses, on cross-examination, made the following statement with reference to the life of typhoid germs:

"My opinion is that in consideration of the facts regarding the Chicago sewage being dumped into the Illinois river, as at present, and the facts concerning the conditions of the Illinois river, that the germs of typhoid fever coming from Chicago sewers would be destroyed en masse by the time the mouth of the Illinois was reached, although some resistant organisms might go beyond that point, such organisms, however, representing a small number, and in my opinion low vitality. My opinion is that the longevity of the typhoid germ depends in

the first place upon its parentage, but in the second place it depends upon the conditions under which the germ is grown, and the conditions with which it finds itself surrounded. In the same way, an individual may come from a healthy parentage and live in a healthy form, but because of conditions surrounding that individual, his vitality may be greatly lowered. Just so with the typhoid germ. Should it struggle, for instance, over periods of time it will lose, in my opinion, the vigor of its life, and be incapable of producing its normal amount of poison. My reason for this belief is, as I have already shown in my direct testimony, that there seems to be a great loss in poisoning power of the germ when the period of time is lengthened between the point of infection of a water and the point of time when such water is drunk. It is a fact that the typhoid fever germs from some typhoid fever patients are possessed of a greater vitality than the germs from other typhoid fever patients. This is true with reference to pathogenic germs in general, for the same reason that a crop of turnips grown upon a good soil would be better than grown one upon a poor. My opinion is that it will be impossible to tell what shall be the longevity of specially resistant cells. Experimental data have shown that for the general mass the longevity is fairly well fixed, so that a good deal of knowledge has been obtained with reference to the average germ, although we are still in ignorance as to the longevity of specially resistant individuals. It is my opinion that these specially resistant cells at their point of departure from the human body are fully as capable or even more fully capable of producing disease than the greater numbers of their less resistant brethren, with whom they start upon their journey, after leaving the body. Whether they arrive, after the interval that may be chosen for the period of investigation, in a condition to produce disease, may be open to question, because the mere fact of their being resistant enough to arrive living does not mean that they will have enough toxin producing powers left to form that serious poison which may cause disease. This, however, is a matter of speculation. (Mason's testimony, Vol. 7, pp. 6960-1-2.)

In his cross-examination, Dr. Barker said in response to a question as to how long typhoid fever germs would live in ordinary river water:

"Well, I should think it would be only a case which would be mere opinion; I should think they would, or might, live as long as ten days. I don't think they would live as long as thirty days." (Barker's testimony, Vol. 8, p. 7167.)

Dr. Barker, in his cross-examination, in Vol. 8, page 7131, testified as follows:

"Q. Do you mean to class yourself as an epidemiologist when you say that the typhoid fever germs will live in the Missouri, the Mississippi and the Illinois river only from five to seven days?

"A. I do not say that. I didn't say that they had lived in those rivers only from five to seven days.

"Q. How long would you say they would live?

"A. I did not say how long they would live.

"Q. How long will they live?

"A. I do not know, nor is there any way at present of finding out." (Barker's cross-examination, Vol. 8, pp. 7131-34-35.)

Mr. Hill, one of the defendants' witnesses, made personal observations as to longevity of typhoid fever germs in the waters of the Delaware river, and found their life history to be limited to from five to eight days. Determinations were also made with reference to the longevity of the germs in the waters of the Schuylkill, a more polluted stream than the water of the Illinois river. From these experiments they were shown to have been alive up to a period of eight days, and, based upon these experiments, Mr. Hill expressed it as his opinion that the life of the typhoid organisms in sewage polluted water under normal conditions which prevail in the majority of the rivers of the United States to be placed at from five to eight days. (See Hill's testimony, Vol. 8, pp. 7509-16-17-18.)

Several experiments were made by Professors Jourdan, Zeit and Russell for the purpose of determining, if possible, the

longevity of typhoid fever germs in the Chicago river, the drainage canal and the Illinois river. These experiments, as heretofore stated, were made by means of parchment and cellodin sacs. The water from the stream was placed in the sacs, and to this was added a large number of typhoid bacilli. The sacs were then suspended in a running stream and from day to day samples were taken from the streams and examined for the purpose of determining if typhoid bacilli could be discovered therein. In the waters of the Drainage Canal Prof. Jourdan discovered three typhoid bacilli from 37 colonies picked from the plate used, one cubic centimetre of water being plated, the water of the drainage canal having been contained in the sac suspended in the water for a period of ten days. (See Jourdan's testimony, Vol. 7, pp. 6198 to 6239, inc.)

At page 6239 of the record, Prof. Jourdan, speaking of the longevity of typhoid bacilli, made the following statement:

"Remembering that the upper stretches of the Illinois river are highly polluted with sewage, and that considerable additions of sewage are made to the Illinois river at points along its course, I do not believe that bacilli introduced into the Des Plaines or upper portion of the Illinois river would live under natural conditions more than five or six days."

Prof. Jourdan, at Vol. 7, page 6276, further says:

"It is of course well recognized that in rural communities a longer period may elapse after the discharge of typhoid bacilli from the bodies of typhoid patients before the bacilli enter water courses, than is the case with such discharges in an urban community furnished with a sewage system. It is also well known that typhoid bacilli in the infections or infectious discharges from the bodies of typhoid patients, when emptied into a loosely constructed privy vault or outhouse may retain their vitality and virulence for a long period. Such was the case in the Plymouth epidemic, already cited.

"Typhoid bacilli have been known to retain their vitality for upwards of five months in the contents of privy vaults. It is evident that if the contents of such vaults or outhouses be

washed down into a stream by heavy rains or melting snows, or if the contents of such vaults be spread as manure upon fields near the banks of a river or other stream, the bacilli may find their way into the water course."

And it has been shown that typhoid bacilli will live longer in relatively pure water in the presence of a relatively small amount of organic matter than in polluted water charged with the sewage of a great city.

So it seems they do live for at least a period of from ten to twenty days with strongly vitalized organisms surviving a very extensive and uncertain time in the waters of a polluted stream.

Experiments upon the longevity of the typhoid bacillus have been made in the laboratory where the question of motion, sunlight and air were taken into account, and it was found that it varied from a period of some weeks to some months. (Whipple, cross-examination, pages 2081-2.)

In reference to the longevity of typhoid fever germs in connection with sewage polluted water, Prof. Sedgwick said:

"Here also my ideas have undergone some change in late years. Broadly speaking, the tendency has been to come to the belief, or has been to show or to indicate greater longevity. Laboratory experiments have sometimes indicated short and sometimes longer longevity. Practical experience has tended to make us believe in greater longevity than that formerly entertained. I have reference to the various conditions in streams. My belief is that in sewage polluted streams, typhoid germs might live in gradually diminishing numbers for weeks, months or even years. I consider that, even though the number of colon bacilli be shown by occasional tests in the water of the Illinois river to be no higher today than they were before the opening of the drainage canal, the mere fact that the addition of vast population contributing sewage to the Illinois river constitutes and must always constitute an added menace to the health of people using the water of the Illinois river at its mouth or below it, and I may add that I have this opinion, or I will say for the reason that bacteriological examination cannot always be made

at the very moment or at all times and seasons of the year and are at best not absolute guides as to the sanitary condition of the water, there might be times and seasons when the material would flow by escaping analysis and pass on and do harm to the people below. Assuming that the germs of typhoid fever come from the sewers of Chicago, and pass by way of the drainage canal and Lake Peoria, large numbers of them might be deposited in the bed of Lake Peoria for the period of months, and if so deposited would not be entirely destroyed at the end of that time. If the accumulation of typhoid fever germs is formed in slack water basins of the Illinois river, which might be true especially in the case of a large amount of typhoid fever in Chicago, they would result in a storage there of a vast number of germs and a sudden flood would sweep them out and bring about such conditions that more typhoid germs would be flowing in that stream than in the drainage canal itself. I know of an excellent instance in a stream, and I think there have been some in lakes, some cases of that sort in lakes or sluggish bodies of water. The best example we have of such an effect on streams, and it happens to be one accompanied with slack water so we have the double demonstration in one case, and that is the well known case of typhoid fever in Detroit resulting from the dredging of Black river at Port Huron, which caused the carrying of the detached sediment down the St. Clair river and through St. Clair lake and into the intake of the Detroit waterworks. That was in 1892, and is probably the most striking case we have on record. It was very thoroughly investigated, and I am familiar with the data on which the conclusions were based, and in my opinion it was a well established case, and is the best that I know of. (Sedgwick's Testimony, Vol. 3, pages 2197-8-9.)

A striking instance of the life of typhoid bacilli in sewage polluted water is found in the case of the epidemic of typhoid at Lawrence, described by Prof. Sedgwick, as follows:

"The mouth of the Lowell sewers is about nine miles above the intake of the Lawrence waterworks. From that point the water was pumped to the reservoir of the city of Lawrence, and in that reservoir *was kept for a period varying from one to more than two weeks. If we add to this one or two weeks the time*

spent in flowing the nine miles and through the pump, which I suppose, or which I know from observation, would be a short time, we may say the period was some time probably as long as fourteen days or more for that amount of the storage proved to be some protection undoubtedly to the people in Lawrence, but an inadequate protection, because they suffered relatively more from typhoid fever than the people of Lowell did, although they were not so near the sewers as Lowell. I may add that the difference between the Lowell and Lawrence reservoirs was very striking and very interesting. The Lowell reservoirs were so arranged that the water passed in and out almost immediately, and the number of bacteria in the Lowell water was sometimes quite high, because of this absence of adequate storage. *In Lawrence the storage was longer*, and was undoubtedly protection of a certain sort, a certain imperfect sort, to the people of Lawrence, but it did not protect them adequately or perfectly. The difference of infection of course was immense. Lowell received the germs from Stony Brook, and Lawrence received those same germs, all that Lowell had not taken out, and in addition the germs from upwards of 1,000 cases in Lowell, and we say the storage was a certain protection, but the mortality was considerably higher in Lawrence than it was in Lowell. (Vol. 3, pages 2237-2238.)"

Covington, Kentucky, and New Albany, Indiana, are well known instances of these retentive life powers of typhoid fever germs. At Covington, Kentucky, the water of the Ohio river, more or less polluted from the streams above, is kept as long as thirty-two days, and yet the city suffers severely from typhoid fever, apparently due to infected water.

At New Albany, Indiana, on the same stream the storage is about a month in sedimentation basins, but typhoid fever is high in New Albany, showing conclusively that storage for a period of even as long as a month cannot be depended upon to remove typhoid germs. (Sedgwick's testimony, Vol. 3, page 2238.)

At Zurich, Switzerland, a typhoid epidemic was clearly traced to the stirring up of sediment near a broken intake pipe. There

is an abundance of evidence showing the prolongation of life of the typhoid germs in sediment and highly polluted waters, and reasoning from analogy from the general behavior of bacteria and largely from epidemiological evidence carefully and systematically presented, and from the fact that freshets are apt to cause and do cause epidemics of typhoid fever in communities using water derived therefrom, and with the contemporaneous occurrence of the epidemic which would explain such increase of epidemic, in streams existing above, we are led to the unalterable conclusion that heaps of material at the mouths of sewers, or in running streams, when stirred up, cause epidemics of typhoid fever. (Sedgwick's testimony, Vol. 3, pages 2310, 11, 12 and 13. Williams' Testimony, Vol. 3, pages 2444-5; 2458-9.)

18.

THE VELOCITY OF THE ILLINOIS RIVER WATER, OR THE TIME IN WHICH IT TRAVELS FROM CHICAGO TO ST. LOUIS.

It is necessary to know approximately the time required for water to pass from Chicago to St. Louis in order to determine whether or not typhoid fever germs and other pathogenic bacteria will pass from Chicago to St. Louis alive and virulent. For the purposes of this investigation Prof. Van Ornum, of Washington University, was requested to make and did make a scientific determination of the velocity of the stream from Lake Michigan to St. Louis, beginning at Chicago, passing through the Chicago river, the drainage canal, down the Des Plaines river, and Illinois river and Mississippi to the Chain of Rocks. This experiment was made in March, 1903, at a time, it is true, when the water in the river was reasonably high. This experiment was made by means of floats specially prepared for the purpose, which met with the least possible resistance during the journey. It was found that the time required for water to pass from Lockport, opposite the Bear Trap dam, to the intake at Chain of Rocks, St. Louis, was nine full days and three minutes, which, added to thirty-four hours and twenty-six minutes,

required to pass through the drainage canal from the South Branch of the Chicago river to opposite the intake at the Chain of Rocks, complete the full journey in 10 days, 10 hours and 29 minutes. When the floats came down the Mississippi river, it will be observed from the demonstration of Prof. Van Ornum, that the wind was blowing (if any possible effect could be produced) so as to carry them up stream, and regardless of this fact each of the three floats deposited in the Illinois river at Grafton passed down the Mississippi over to the western side and between the intake of the St. Louis waterworks and Missouri shore. (See Van Ornum's testimony, Vol. 2, pp. 1724 to 1746; and also Complainant's Exhibit 40.)

These experiments were carried on by Prof. Van Ornum, together with the assistance of Mr. C. V. Mersereau, Frank J. Brown, J. E. Gibson and T. F. Reed, whose testimony will be found in Vol. 2 from pages 1793 to 1835, inclusive. In this connection Mr. Williams made a careful estimate of the time required for water to travel from Lakeport to the intake of the St. Louis waterworks, based on the gauges of the Illinois river, together with the flow of the river from Chicago to St. Louis, considering it at these various points. He found under the conditions which existed since the opening of the drainage canal that the water of the drainage canal, something over three hundred days in a year, would reach the intake of the St. Louis waterworks in from nine to fifteen days from the time it left the Bear Trap dam; that a portion of the infection contributed or water added might be delayed considerably beyond this time, but that he was quite certain that most of the mixed water and sewage of Chicago would reach the Mississippi river at the Chain of Rocks within the period above mentioned.

(See Williams' testimony, Vol. 3, pp. 2434, 2437-38.)

Albert S. Crane, the defendant's witness, testified, after qualifying, that he had prepared the chart introduced into evidence by this witness, Mr. Hering, which will be found on page 7001 of the printed record, under the caption, "Sanitary District of Chicago, Schematic representation of the self-purification of

the waters of the Missouri, Mississippi and Illinois rivers between the points indicated, based upon the length of life of the typhoid bacillus, as fixed by experiments made under the directions of Hiram F. Mills," the results of which will be found under the heading of the paper entitled "Typhoid fever in its relation to sewage supply." This chart was made under the direction of Mr. Hering, one of the defendant's principal witnesses, and a gentleman who was the chairman of a commission which recommended the construction of the Chicago Drainage Canal. The data for the profiles, including the Mississippi, the Missouri and the Illinois rivers, were taken from a paper published by the Department of the Interior, entitled "Water Supply and Pollution," General Survey No. 44. These figures were used entirely in the profiles, except on the upper part of the Illinois river where other figures were taken in order to make the profile more in detail. These latter figures were taken from a report made by Lyman E. Cooley, entitled "Waterway from the Lakes to the Gulf." In this the distance from the mouth of the Illinois river at Grafton to St. Louis is calculated at 38 miles, and from the mouth of the Illinois river at Grafton to the upper dam at Joliet is fixed at 325 miles, while the distance from dam No. 1 at Joliet to Lake Michigan is given at 38½ miles. The actual time of flow as representing the minimum time has been corrected for mean time of flow. The mean time flow was taken as .8 of the minimum. Fifteen days was given as the shortest time that the floats in the test carried on, under the supervision of Mr. Rudolph and Mr. Crane, would pass from Chicago to St. Louis, which under the corrected time, is determined at 18½ days. The velocity of the Mississippi and Missouri was computed, first, by the mean discharges of the two streams, on the Mississippi at Grafton and on the Missouri river at St. Louis. They were found to be 57,000 and 120,000 cubic feet per minute, respectively. The data with reference to the flow of the Mississippi and the Missouri were obtained by using the reports of the Mississippi River Commission, entitled "Tabulated results of discharge measurements of the Mississippi river and its tributaries and outlets for the years 1838 to 1898," and plotting these to form a discharge curve. In the case of the Mississippi

river, the average gauge readings at Grafton were taken for the years 1890 to 1894, inclusive, and then for the Missouri river the years 1895 to 1899, inclusive. After these average stages were obtained the average discharge was obtained directly from the curve. The chart showing the curve of the respective rivers will be found at page 7011 of the record. In the tabulated results o fthe Mississippi river above referred to are found a large number of discharge measurements, together with the gauge readings, mean and maximum depths, width of the river and velocity in feet per second. The discharges at the various towns along the river are also computed, and by looking in the table the velocity at these towns or a part of them will be found. The velocity of the river between these towns is taken as the velocity at the gauging stations and the time computed by using the velocity and the distance. This course was pursued for both the Mississippi and the Missouri rivers. The curves were obtained by using the data obtained by the Massachusetts State Board of Health and published in a report of the State Board of Health of Massachusetts, entitled "Typhoid fever in its relation to water supply, by Hiram F. Mills." The results there given were embodied in a curve and from the curve the following is deduced:

100 per cent of the bacteria were living on the first day.
73.4 per cent of the bacteria were living on the third.
50.8 per cent of the bacteria were living on the fifth.
30.8 per cent of the bacteria were living on the seventh.
14.1 per cent of the bacteria were living on the ninth.
5.2 per cent of the bacteria were living on the eleventh.
2.5 per cent of the bacteria were living on the thirteenth.
1.6 per cent of the bacteria were living on the fifteenth.
1.0 per cent of the bacteria were living on the seventeenth.
0.4 per cent of the bacteria were living on the nineteenth.

Assuming that the number of typhoid bacilli contributed was proportional to the population, the curves were started at the extreme from St. Louis. Working towards St. Louis, the results for the first, third, fifth, etc., days were plotted. These curves were plotted for each city in turn. The results at St. Louis were so arranged that the result for the Illinois river was

placed opposite the combined results of the Missouri and Mississippi rivers so that they can be directly compared. The variations between the Illinois, the Mississippi and the Missouri river, as indicated on this chart, show that the Illinois river has the effect of a city of 13,000 situated immediately above St. Louis, the Missouri River a city of 96,000, and the Mississippi river a city of 107,000, or a relation of 13, 96 and 107. In making this chart, Mr. Crane based the same upon the following populations:

Missouri river:	
Omaha, South Omaha and Council Bluffs	154,000
Plattsmouth	4,964
Nebraska City	7,380
St. Joseph	103,000
Atchison	15,700
Leavenworth	20,700
Kansas City	215,000
Independence	6,974
Lexington	4,190
Boonville	4,377
Jefferson City	9,664
St. Charles	7,982
The Mississippi river:	
Minneapolis and St. Paul, combined	365,783
Red Wing	7,525
Winona	19,714
LaCrosse	28,895
Dubuque	36,297
Galena	5,005
Clinton	22,698
Davenport, Rock Island and Moline	71,995
Muscatine	14,073
Burlington	23,201
Ft. Madison	9,278
Keokuk	14,641
Quincy	36,252
Hannibal	12,780

Louisiana	5,131
Alton	14,210
The Illinois river:	
Chicago	1,698,000
Joliet	29,353
Morris	4,273
Ottawa	10,588
LaSalle	10,446
Peru	6,863
Spring Valley	6,214
Peoria	56,100
Pekin	8,420
Beardstown	4,827

It will be observed from the foregoing chart and statement that 18½ days was used as the time for the water to pass from Chicago to St. Louis. If this time limit be decreased to ten days, which is more than the time limit as shown by the experiments conducted by Prof. Van Ornum, the result will be that the sewage from the city of Chicago, containing two millions of people, together with the sewage discharged from the cities discharging along the Illinois river, would result in sufficient typhoid dejecta passing from those cities to the city of St. Louis equal to the typhoid dejecta discharged into the river by a city having a population of 160,000 people, and according to the total per cent and the testimony of Mr. Hering and Mr. Crane, would result in the establishment of a city immediately above St. Louis having a population of 160,000 people. It might be well here to remark that as the velocity of the waters of the Illinois river increase according to the volume therein contained, that this imaginary city would rise and fall in increasing proportions with the increased velocity of water coming down from Chicago to St. Louis. This, in our judgment, is a very striking example of the effect of the Chicago sewage upon the waters of the Mississippi river at the intake, based upon the typhoid longevity of Hiram F. Mills, which is the one practically used by all sanitarians and scientists, showing conclusively and strikingly the very marked effect of the waters of the Illinois river upon the

Mississippi river, and which demonstrates unquestionably the fact that large quantities of typhoid fever germs pass from Chicago to St. Louis. (See Hering's testimony, Vol. 7, pp. 7000 to 7029.) (Crane's testimony, Vol. 7, pp. 7008 to 7018, inclusive.)

Mr. Alvord, one of the complainant's rebuttal witnesses, prepared a similar chart to that prepared by Mr. Crane, being a schematic representation of the reduction of typhoid bacterial pollution in Illinois rivers, using the same data as proposed by Mr. Hering and Mr. Crane in their diagrams and chart. The chart prepared by Mr. Alvord is found at page 7782 of the record. This chart demonstrates clearly the proportionate numbers of bacteria that reach the city of St. Louis from Chicago through the Drainage Canal, the Illinois river and the Mississippi river, based upon the table prepared by Mr. Hiram F. Mills, which is generally relied upon by sanitarians in their investigations of water supplies. Mr. Alvord based the chart upon 20 deaths per 100,000 population, while Prof. Van Ornum's estimates as to the velocity of the river from Chicago to St. Louis were used instead of the velocity found by Prof. Randolph. The curve plotted upon the chart indicates the relative typhoid bacterial pollution, so far as the same can be predicated upon the population, by using the bacterial reduction found in the experiments of Hiram F. Mills and substantiated by Dr. Horrocks. This chart, together with the chart prepared by Mr. Hering, has reference to bacteria coming from patients who have died of the disease. It may also be considered as applying to patients on the Illinois river watershed sick of typhoid fever and who survived. Assuming active typhoid contamination to be proportioned to the population, and assuming diminution in the number of typhoid germs day by day to be as shown in the experiments of Mr. Hiram F. Mills, and basing the normal flow in the Illinois river from Chicago to St. Louis at about 15 days, the typhoid infection reaching the city of St. Louis from the population upon the Illinois watershed, calculated upon a death rate of 20 deaths per 100,000 population, would represent a city of 90,000 people, while on the basis of the flow as gauged by Prof. Van Ornum in his testimony, the infection arising at the Chain of

Rocks, at St. Louis, would be equivalent to the population of a city of 400,000. This city would be situated immediately above the intake tower, with a typhoid death rate of 20 deaths per annum per 100,000 population.

With a maximum flood, such as occurs only once every seven years, it appears that the comparative pollution reaching the intake of the St. Louis waterworks would be equivalent to a population of a city of 960,000 with a typhoid fever death rate of 20 deaths per 100,000 living, this latter assumption being based upon the movement of the pollution vehicle from the Chicago river to the Chain of Rocks in eight days. (See Alvord's testimony, Vol. 8, pp. 7781-87, inc.)

It will also be noticed that based upon the typhoid death rate of 20 deaths per 100,000 population per annum, the death rate at Chicago for the year 1902 represents a population of 3,750,000, for 1903, 2,950,000, for 1900, 1,685,000, 1901, 2,505,000. The above figures, however, represent a greater population than actually exists in Chicago, but at the same time they represent the population of a city where the typhoid mortality rate is not more than 20 deaths per 100,000 population.

19.

ST. LOUIS WATER SUPPLY RENDERED UNFIT FOR DOMESTIC USE BY BEING POLLUTED WITH THE SEWAGE OF CHICAGO AND INFECTED WITH PATHOGENIC BACTERIA AND DISEASE PRODUCING ORGANISM FROM THE SEWERS OF CHICAGO.

The impurities increased very rapidly in the St. Louis water after the opening of the Drainage Canal. Throughout the entire time of this examination analytic results showed the water of the Mississippi river in an unsanitary condition. It was water that would be condemned by water specialists. The figures for nitrites and free ammonia being far beyond those allowed in the potable water.

(Prof. Keiser's testimony, printed record, Volume 2, page 1073.)

It will also be observed that the chemical observations of the water of the Mississippi and Missouri rivers show these two waters to be of a stable character, while the water in the Illinois river exhibits a very unstable character. This stability of the upper Mississippi river and the Missouri river waters is made apparent from the fact that the analysis shows the larger portion of the polluted material to be of a vegetable character, while the contaminating constituents contained in the water of the Illinois river is shown to be one from nitrogenous animal matter.

(Prof. Keiser's testimony, printed record, Volume 2, page 1077.)

A general comparison of the result of the analysis of water collected at Grafton, Illinois river at Grafton, Mississippi river above Grafton, St. Louis Intake Tower, Missouri river at Fort Bellefontaine, in the period 1899-1900, respectively, it is noticed that a general increase takes place in nitrites and free ammonia in the waters of the St. Louis Intake in 1900 over conditions existing in 1899. The water discharged in the Mississippi river at Grafton is unquestionably more polluted in 1900 than in 1899. This increased pollution of the Illinois river necessarily results in an increased pollution in the Illinois river at Hartford and at the Intake. The result shows that the water entering the Intake in 1900 was more polluted than in 1899. This increased pollution, with no corresponding increase pollution in the Mississippi river above the mouth of the Illinois or the Missouri river above its mouth, must of necessity be attributed to the increased pollution of the Illinois river in 1900. The increased pollution of the Illinois river in 1900 is shown by the chemical analyses made by Dr. Teichmann following the opening of the Drainage Canal at Chicago, and thus we conclude that the opening of the Drainage Canal resulted in an increased pollution of the St. Louis water supply.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1245-1246-1247 and 1267.)

What is said with reference to the Illinois river during the period 1900, is also found to exist during the entire year of 1901.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1268-1269.)

During the period 1901, free ammonia was much lower in the Mississippi river above the mouth of the Illinois river than the water in the Illinois river above Grafton. Free ammonia at Alton and Hartford and St. Louis Intake was much larger than in the Mississippi river above Hartford or the Missouri river at Fort Bellefontaine. The final results as to chlorine, nitrates and nitrites, show that the contaminating products in the waters of the Mississippi river at the Intake are due to the unsanitary condition of the Illinois river rather than that of the upper Mississippi river and the Missouri.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1270-1276, inc.)

At page 1306, Volume 2, Professor Teichmann testified substantially thus:

"After having examined these waters chemically in the manner in which you described, and after having had considerable experience in water analysis, I am able to state that the outfalls of the sewers in Chicago passes into the Drainage Canal, from thence into the Des Plaines and Illinois rivers, the Mississippi river, and from thence into the Intake of the St. Louis water supply, and that the sewage of Chicago will this way enter into the St. Louis water supply and is distributed to the people of St. Louis. I am further able to state from my examination and experience that the water supply of the city of St. Louis, since the opening of the Drainage Canal, has become more polluted by reason of the opening of the Chicago Canal and the inflow of the sewage from the city of Chicago, than it was prior thereto."

In cross-examination, page 1445, Professor Teichmann said: "I consider it in a measure as very striking that with the increase of the pollution of our water supply, and with the in-

creased pollution of the Des Plaines river from the Drainage Canal, and the Illinois river and the Mississippi river down to the Intake in the year 1900, there was a corresponding increase in typhoid fever of 1300 per cent over the average of the five years preceding. In other words, that almost a typhoid fever epidemic followed the pollution of the water supply at the opening of the canal, as traced up the Mississippi river, then up the Illinois river and the Des Plaines river into the Chicago Drainage Canal, and that this high pollution of the Mississippi river, caused by the Illinois, produced an effect upon the typhoid condition in St. Louis never before experienced in that city during the month of March, and that the city never experienced such high pollution, such sewage polluted water as went into the Intake Tower, through the reservoir and distributed to the people of St. Louis, as in the month of March, 1900."

By comparing the analytical results of 1899, prior to the opening of the canal, with those of 1900, 1901 and 1902, after the opening of the canal, it will be found that the water became worse in its chemical character since the opening of the canal.

A very remarkable presentation of the effect of the sewage of Chicago upon the water of St. Louis is shown by the testimony of Professor Keiser, volume 2, pages 1697 to 1710, which is herewith presented verbatim, in order that its full effect may be readily observed:

"Q. Professor Keiser, I will ask you if you have made an examination, from data furnished you by the Board of Health of the city of St. Louis, of the condition of the water supply of St. Louis, and subsequent and prior to and after the opening of the Chicago Drainage Canal?

"A. Yes, sir.

"Q. Will you state briefly the result of your examination?

"Q. State where you got the data?

"A. I obtained the data from the Water Commissioner of St. Louis, Mr. Edward Flad, and from the office of the City Chemist, Dr. Teichmann. I received it from Dr. Teichmann, also some data from my own laboratory, the Washington University chemical laboratory.

"Q. Now, you may state the result of your examination?

"A. In the first place, I have tabulated all the analyses that were made of the waters of St. Louis prior to the opening of the Chicago Drainage Canal, and I find that the records go back to the year 1894. In the first place, there are reported seventeen analyses of water from the distributing well. These analyses were made from May 2, 1893, to January 24th, 1894. They are reported in the Mayor's message—the Mayor of St. Louis, annual message for 1894, page 418, and here are these analyses taken out of the Mayor's message for 1894 (exhibiting sheets of paper). The average results as here printed for the condition of the water supplied to St. Louis are as follows:

Free ammonia—this is the average of the seventeen analyses—free ammonia .046.

Nitrites—that means parts per million of nitrogen—nitrites .003 parts per million.

Albuminoid ammonia 1.033 and nitrates .38 parts per million.

Then we have in the same report seventeen analyses of water from the settling basins made from April 14th, 1893, to January 24th, 1894, and they gave the following average results:

Free ammonia	.019
Nitrites	.002
Albuminoid ammonia	.411
Nitrates	.44

"Then a series of twenty-one analyses were made at intervals from December 15, 1892, to April 20th, 1894, in the chemical laboratory of Washington University. They gave the following average results. These are the originals, the twenty-one analyses. Now the average at the bottom is as follows:

"Free ammonia	.048
Nitrites	.005
Albuminoid	.310
Nitrates	.38

"In addition to these results, twenty-six analyses were made by the city chemist of the intake water at intervals from September 9th, 1899, to January 22nd, 1900. The average values for these analyses are as follows:

Free ammonia	.063
Nitrites	.002
Albuminoid ammonia	.552
Nitrates	.39

"Comparing these averages obtained in different years we see that there was but very slight change in the character of the water supplied to St. Louis. The free ammonia ranged between—

"Q. What year are you talking about?

"A. Supplied to St. Louis previous to the opening of the drainage canal.

"The free ammonia ranged between .019 and .063 parts per million. The nitrites varied from .002 to .005; the albuminoid ammonia from .310 to 1.033, and the nitrates were practically constant. The maximum value for free ammonia before the water of the Drainage Canal reached St. Louis was .138 on January 21st, 1900, and for nitrites the maximum value was .01 on the same day.

"These analyses that are recorded prior to the opening of the canal show that the water was comparatively stable, and that it was not an unwholesome water compared with its present condition.

"Q. Now give the condition of the water after the opening of the canal?

"A. On January 17th, 1900, the Drainage Canal was opened. The water must have reached St. Louis about the beginning of February, 1900, and the effect of that opening on the St. Louis water is clearly seen in the results of the analyses made daily during the month of February—twenty-eight daily analyses of intake water made by the City Chemist gave the following values:

"Free ammonia	.217
Nitrites	.013
Albuminoid ammonia	.676
Nitrates	.6

"The impurities tend to increase during March, as is shown by the following value for thirty-one daily analyses in March, 1900:

"Free ammonia	.348
Nitrites	.014
Albuminoid ammonia	1.202
Nitrates	.8

"The average results for April, 1900, were

Free ammonia	.186
Nitrites	.020
Albuminoid ammonia	1.036
Nitrates	.6

"A portion of this increase in free ammonia and nitrites noticed in February and March, 1900, may have been due to the fact that in the winter months impurities usually are found to run higher than in spring and summer, but the increase in the months of February and March, 1900, was very much greater than had been observed in any previous analyses, and further the water from this time on was found to have been permanently changed. Subsequent analyses show that in the spring and summer months, following, the water did not return to its former condition, but had been permanently polluted; thus the monthly averages for April, May and June, and for each following month until June, 1901, are as follows: And I have here a table:

"Said table is in words and figures as follows:

	Free Am.	Nitrites.	Alb. Am.	Nitrates.	Chlorine.
April, 1900,	.186	.020	1.036	.6	9
May, 1900,	.094	.011	1.190	.5	10
June, 1900,	.070	.004	1.148	.3	11
July, 1900,	.127	.004	1.350	.3	10
Aug., 1900,	.101	.005	.810	.4	12
Sept., 1900,	.093	.004	.818	.7	15
Oct., 1900,	.118	.006	.898	.6	9
Nov., 1900,	.098	.007	.705	.6	10
Dec., 1900,	.105	.011	.289	.4	17
Jan., 1901,	.144	.009	.396	.8	19
Feb., 1901,	.121	.007	.296	.7	19
Mar., 1901,	.310	.013	1.455	1.3	11

April, 1901,	.191	.016	1.034	1.1	6
May, 1901,	.088	.002	.506	.4	9
June, 1901,	.105	.002	1.161	.5	10

"A. (Continuing): The average results for this table are as follows:

Free ammonia	.150
Nitrites	.009
Albuminoid ammonia	.880
Nitrates	.6

"Comparing this now with the average result before the opening of the canal, namely,

Free ammonia	.063
Nitrites	.002
Albuminoid ammonia	.552 and
Nitrates	.39

We see that there has been a very decided increase in each of these forms of nitrogen, and that the chemical analyses show a permanent pollution of the water.

"According to generally accepted standards of potability a water having .150 parts of nitrogen as free ammonia, and .009 parts of nitrogen as nitrites, would be condemned as unsanitary.

"Q. Now give us the sanitary condition of the Missouri river water before and after the opening of the Drainage Canal.

"A. In looking over the statistics of the Health Department of the city of St. Louis, I found eleven analyses of water of the Missouri river taken at a point above the mouth of the stream, are on record in the Health Department of the city of St. Louis.

"The average results of these analyses were:

Free ammonia	.080
Nitrites	.001
Albuminoid ammonia	.657
Nitrates	.4

And the average values of eight analyses made in the chemical laboratory of Washington University of Missouri river water taken at Fort Bellefontaine, Missouri, from January 23rd to January 31st, 1900, are as follows:

Free ammonia	.134
Nitrites	.008

Albuminoid ammonia	.342
Nitrates	.39

"The average of all these recorded analyses of Missouri river water prior to February 1st, 1900, are as follows:

Free ammonia	.107
Nitrites	.0045
Albuminoid ammonia	.499
Nitrates	.39

"After February 1st, 1900, daily analyses of Missouri river water were made by the City Chemist until October 10th, 1900, and also during the period October 1st, 1901, to November 30th, 1901:

Free ammonia	.142
Nitrites	.007
Albuminoid ammonia	1.203
Nitrates	.5

"And for the second period the averages are:

Free ammonia	.069
Nitrites	.003
Albuminoid ammonia	.631
Nitrates	.55

"Now the averages of both of these series are as follows:

Free ammonia	.105
Nitrites	.005
Albuminoid ammonia	.917
Nitrates	.5

"Comparing these averages now with the averages of analyses before February 1st, 1900, namely:

Free ammonia	.107
Nitrites	.0045
Albuminoid ammonia	.499
Nitrates	.39

"We see that there is but a slight difference in the average condition of the Missouri during these two periods. In other words, the Missouri river during the period of September 2nd, 1899, to November, 1901, has undergone no permanent change in the sanitary character. The same fact is shown by comparing the average results obtained by the City Chemist on September

2nd to December 4th, 1899, with the average results obtained by him in October and November, 1901. Those analyses in the form of an average give

Free ammonia	.080
Nitrites	.001
Albuminoid	.657
Nitrates	.4

"In the later period, which was two years later, but at the same time of the year, we find

Free ammonia	.069
Nitrites	.003
Albuminoid ammonia	.631
Nitrates	.55

"We see from these that while St. Louis water had undergone a marked deterioration, the Missouri river water had remained unchanged. It is true that in the winter months the impurities in this river are higher than in the summer. This is true of all streams, but we see that in the fall of 1901 the water had again returned to its former condition. The results show, then, that the increase of impurities in the St. Louis water did not come from the Missouri river.

"Q. Those are conclusions arrived at based upon the data which you have given, are they not?

"A. They are.

"Q. Now give us the sanitary condition of the Mississippi river before and after the opening of the drainage canal.

"A. There are recorded in the Health Department of the city of St. Louis, analyses made by the City Chemist, seventeen analyses of the Mississippi river collected at Hartford, Illinois, a point about one mile above the mouth of the Missouri river. These samples were collected at intervals between August 3rd, 1899, and December 4th, 1899. The average results of these analyses are as follows:

Free ammonia	.107
Nitrites	.004
Albuminoid ammonia	.622
Nitrates	.5

"These were all made before the opening of the drainage canal. After the opening daily analyses were made from January 23rd, 1900, to October 10th, 1900, upon samples taken at Hartford. The average values for these analyses are as follows:

Free ammonia	.275
Nitrites	.018
Albuminoid ammonia	.613
Nitrates	.7

"Daily analyses were also made from October 1st, to November 30th, 1901, and the averages obtained were:

Free ammonia	.062
Nitrites	.011
Albuminoid ammonia	.368
Nitrates	.54

"Averaging both series that were made subsequent to the opening of the drainage canal we get:

Free ammonia	.236
Nitrites	.017
Albuminoid ammonia	.568
Nitrates	.67

"Comparing these results with the average condition of the Mississippi river at the same point before the opening of the canal, namely:

Free ammonia	.107
Nitrites	.004
Albuminoid ammonia	.622
Nitrates	.5

We see that there has been a permanent increase of the pollution of the water. The water of the Mississippi like that of the St. Louis intake has been very materially inferior in sanitary quality since February, 1900, and further, these analyses show that since the St. Louis water is a mixture of the water of the Missouri and the Mississippi the increased impurities of the St. Louis water must have come from the Mississippi river, and not from the Missouri river.

"Q. Now give the condition of the Mississippi river above the mouth of the Illinois river.

"A. It having been shown by the previous analyses that the Mississippi river is a carrier of the impurities to the St. Louis intake, it is now of importance to determine how these impurities find their way into the Mississippi. The question arises: Do these impurities come down the main stream of the river or from the Illinois river? Eighteen samples of water were taken from the Mississippi river at a point above the mouth of the Illinois river. These samples were collected at intervals between September 6, 1899, and January 17th, 1900. The average values of the analyses made by the City Chemist are as follows:

Free ammonia	.069
Nitrites	.002
Albuminoid ammonia	.503
Nitrates	.3
Chlorine	6.0

"Daily analyses of the water from this point were also made from January 23rd, 1900, to October 10th, 1900. The averages obtained are as follows:

Free ammonia	.138
Nitrites	.008
Albuminoid ammonia	.587
Nitrates	.46
Chlorines	5.0

"Daily analyses were again made from October 1st to November 30th, 1901, and the averages obtained were:

Free ammonia	.057
Nitrites	.001
Albuminoid ammonia	.348
Nitrates	.1
Chlorines	4.3

"Comparing these with the results as given, we see that the Mississippi river above the mouth of the Illinois, while higher in impurities in the winter months, returned in the fall of 1901 to a condition very similar to that which it was in 1899. The amounts of free ammonia and nitrites are relatively low in this stream and it is very similar in sanitary character to the Missouri river above its mouth. Plainly then, the upper Mississippi

is not the source of the impurities that pollute St. Louis water.

"Q. Now, professor, give the results of the analyses of the Illinois river made three miles above Grafton.

"A. Nineteen samples of the water of the Illinois river from a point three miles above Grafton were collected and analyzed by the City Chemist at intervals between September 6th, 1899, and January 17th, 1900. That was before the opening of the canal. The average values found are as follows:

Free ammonia	.215
Nitrites	.012
Albuminoid ammonia	.553
Nitrates	.8
Chlorine	25.0

"These results show that at this time the water was badly polluted and not fit for drinking according to accepted standards. From January 23rd to October 10th, 1900, daily analyses were made of water from the same point, and again in October and November, 1901. The averages for the first series are as follows:

Free ammonia	.272
Nitrites	.032
Albuminoid ammonia	.509
Nitrates	.96
Chlorine	13.0

"For the second series:

Free ammonia	.110
Nitrites	.043
Albuminoid ammonia	.373
Nitrates	1.71
Chlorine	21.6

"The average values for both series of analyses are as follows:

Free ammonia	.239
Nitrites	.034
Albuminoid ammonia	.482
Nitrates	1.11
Chlorine	14.7

"We see from these that for the ten months since the opening of the drainage canal there was an increase in free ammonia of nearly 27 per cent and of nitrites of 167 per cent. We can only conclude from these figures that after the canal was opened there was a much larger quantity of sewage undergoing putrefactive changes than before in 1901, although the proportion of free ammonia had fallen somewhat, the nitrites had gone up to .043 parts per million, an increase of 258 per cent over what they were before the opening of the drainage canal. The Illinois river is thus shown to be the stream which, with its high free ammonia and nitrites, contaminates the Mississippi, and the Illinois river at its mouth is found to be in a much more polluted condition since January 23rd, 1900, than it was prior to that time. It is, therefore, the Illinois river that has caused the permanent increase in the impurities of the St. Louis water. The analyses have shown that both the Missouri river and the Mississippi river above the Illinois have undergone no permanent change, but the Illinois river has been rendered more impure as a result of the opening of the drainage canal.

"Q. Now can you give the condition of the Illinois river at the points above Peoria?

"A. There were no analyses of the water of the Illinois river at points above Grafton made by the City Chemist before the opening of the canal, but from January 23rd, 1900, to October 10th the same year, daily samples were taken at a point three miles above Peoria, and occasional samples at Joliet and at Lockport. Samples were also taken from the Illinois and Michigan Canal and from Lake Michigan. These analyses show that as we ascend the river from Grafton to Chicago, the water becomes steadily more and more impure. This fact is clearly shown by the average values obtained from the Illinois: Thus, the average values from samples taken three miles above Grafton are as follows:

Free ammonia	.239
Nitrites	.034
Albuminoid ammonia	.482
Nitrates	1.11
Chlorine	14.7

"The average values for samples taken three miles above Peoria are as follows:

Free ammonia	.568
Nitrites	.095
Albuminoid ammonia	.284
Nitrates	1.48
Chlorine	.19.4

"And the average values from samples taken at Joliet in 1901 are as follows:

Free ammonia	2.732
Nitrites	.057
Albuminoid ammonia	.425
Nitrates	.22
Chlorine	23.9

"And the averages of samples taken from the Illinois and Michigan Canal are as follows:

Free ammonia	13.250
Nitrites	.009
Nitrates	None
Chlorine	150.0

"The averages from the Drainage Canal, Lockport, Bear Trap Dam, are as follows:

Free ammonia	1.585
Nitrites	.026
Nitrates	.15
Chlorine	15.0

"Now for the sake of comparison, the averages of the water from Lake Michigan are as follows:

Free ammonia	.043
Nitrites	.005
Nitrates	.15
Chlorine	6.0

"Q. Now what conclusions do those results show or lead you to?

"A. We see that the entire Illinois river is in a highly polluted condition. The figures obtained at Joliet and those for the Illinois and Michigan and Drainage Canals are such as would have been obtained from sewage in its early stages of decompo-

sition. Lake Michigan has .043 parts of free ammonia and .005 parts of nitrites. Now by the admixture with the sewage in the Chicago river, we find that when it reaches the drainage canal the free ammonia has increased to 1.585 and nitrites to .026 parts per million. The Illinois and Michigan Canal is still more highly charged with sewage and gives 13.250 parts of free ammonia. These two canals carry sewage into the Illinois river by dilution with the water of the river, we find free ammonia .468 at a point three miles above Peoria. The nitrites, however, at this point are higher, namely .095. Going down then to Grafton we find that the free ammonia has fallen to .239, and the nitrites to .034, but this is still far from being in a condition fit for drinking. We see that the oxidation and self-purification processes become very slow as the concentration of the sewage is diminished, and for the same reason we find these impurities in the water of the Mississippi and in the water of the St. Louis water works."

(Prof. Keiser's testimony, printed record, Volume 2, pages 1697-1710.)

Again, Prof. Keiser testified as follows:

"Q. Professor, I want to ask you this question. You say that you did not consider the chlorine as an element in determining the potability of the water of the Missouri river because you attributed that chlorine to mineral origin and not to vegetable or animal?

"A. Yes, sir.

"Q. Now, isn't it a fact, independent of any knowledge as to the origin of the chlorine, that the water contains high chlorine and low ammonias and low nitrites or an absence of nitrates, that is shows that the chlorines are not attributable to animal or vegetable origin, but must be attributed to mineral origin?

"A. Yes, sir.

"Q. And you found those conditions present in Missouri waters?

"A. I did.

"Q. And that did not apply to any of the other streams?

"A. No, sir.

"Q. So that if you knew nothing about the chlorine in the Missouri, coming from the Kaw river or from any other mineral source, you would still come to the conclusion that they were attributable only to mineral salt source?

"A. Yes, if the ammonias are low. If the ammonias and nitrites are low, and if we find all forms of nitrogen low, low nitrites and low nitrates, then find high chlorine, the water is no longer contaminated and it may show that the water was at one time contaminated, but the forms of nitrogen have been removed, and while the mineral matters may be high, the chlorine might be high, it would in all probability come from salt layers or salt springs.

"Q. And if the chlorine could be attributable to animal or vegetable origin, then you would say as a chemist that the nitrites and the free ammonias must be correspondingly high.

"A. Yes, sir.

"Q. And if they are not, it shows that they did not come from sewage pollution?

"A. Yes, sir.

"Q. And that is the condition of the Missouri river?

"A. Yes, sir."

Prof. Keiser's testimony, printed record, Volume 2, pages 1724-1725.)

In this connection Dr. Ravold testified as follows:

"Q. Now Doctor, I will get you to state whether or not you considered this water potable and safe for drinking purposes that comes from the Intake tower of the St. Louis Waterworks now without filteration and without boiling?

"A. I do not.

"Q. Now, doctor, in the cross-examination of General Hamlin yesterday you persisted in using the term disappearance, asking the question as to whether or not the increase volume of the water by the opening of the Chicago Drainage Canal and pouring the Lake Michigan water into the same thereby caused dilution, would tend to increase the dilution in the Des Plaines river and consequently the disappearance of bacteria of any kind that might be in the water of the Des

Plaines and Illinois rivers, and I want to ask you to explain what you meant by the term disappearance as used in reply to his question?

"A. I meant by this that the bacteria were not killed, they were not destroyed by the dilution, but they were moved farther apart. I said at the time that if we had a gallon of water with 100 bacteria in it and added 99 gallons to it, we would have the first 100 to one gallon and by adding 99 to it, it would be diluted one to 100, and there would then be one bacilli to one gallon of water, the bacilli not having disappeared, but are removed farther apart.

"Q. State whether or not dilution would in any way destroy pathogenic germs.

"A. It does not destroy them.

"Q. I will ask you this question: Do you consider, as a bacteriologist, from your knowledge of water supply of St. Louis prior to the opening of the Chicago Drainage Canal, and your knowledge of said supply since the time of the opening thereof, that the water supply at the Intake tower of this city has been rendered less wholesome and safe for domestic and primary use than before the opening of the canal, and if so, is it occasioned by the waters from the canal?

"A. I think it is less wholesome, and I can prove it chemically and bacteriologically. Do you wish the reason?

"Q. You can state them.

"A. Formerly the sewage of Chicago, before the opening of the Chicago Drainage Canal, was discharged into what was practically a large tank and that was the Chicago river, a river which discharged itself when the lake was lower than the water in the river or when freshets occurred which swept the water of the river out into the lake, which occurred semi-occasionally; but as a rule the water was stagnant in the river containing the sewage. That stagnant sewage putrified, was broken up by aerobic and finally by anaerobic action until the whole river was a fetid, stinking mass. It remained in that river for quite a length of time. In order to purify the river and to create a current in it, pumps were put in at Bridgeport and the sewage pumped into the Illinois and Michigan Canal in certain quan-

tities, a certain quantity was lifted from the South Fork into the Illinois and Michigan Canal. This sewage practically received the treatment afforded by a septic tank and all the pathogenic bacteria were practically dead in it before they reached Bridgeport, because the pumps at Bridgeport made no perceptible current in the Chicago river towards the pumps. I tried this experiment several times myself by throwing a board into the river and watching it for several days and it never moved more than a block either way in 24 hours. So the current towards the pumps was very small according to my actual experience. So, in my opinion, the putrifying material in the river would destroy any pathogenic bacteria, such as typhoid, left in it for any length of time, or for a short time. Now, however, this condition does not obtain, and the typhoid bacteria and other pathogenic bacteria discharged into the stream are hurried through it. In the Chicago river now the rate of flow is something like three miles an hour, sometimes more than that. In August or September of 1901, Mr. Randolph and I watched a boat trying to get by a bridge, and the boat had not enough power to force itself up the river towards the lake in a current then running fully three miles an hour. That was at five o'clock in the evening when the gates were lowered at Lockport and the full quantity, 300,000 cubic feet, was being discharged. The sewage is now carried from the Chicago river into the Drainage Canal, and from there on to Lockport and then into the Des Plaines and Illinois rivers, so that the chances of pathogenic bacteria vitalized and strong as they come from the bowels of an individual, being carried down to St. Louis water supply, is infinitely greater now than when the pumps were at work.

"Q. I will get you to state if you are acquainted with the condition of the Illinois and Michigan Canal, as to whether there is any flow or current in this canal?

"A. There is a current in that canal.

"Q. Is it rapid or slow?

"A. Slow, slow at all the periods when I saw it. There may be periods when it is rapid, but I never saw one of those periods.

"Q. Now, in answer to a question of Gen. Hamlin yesterday you stated that it might be that typhoid bacilli, traveling from the sewage of Chicago by the canal, the Des Plaines, Illinois and Mississippi rivers and coming into the Intake here, of the waterworks of St. Louis, would be, perhaps, less virulent in form than if they traveled a distance of 10 or 15 miles and then came into the Intake, I will get you to state whether or not, if they were still alive, that would prevent them from causing typhoid fever?

"A. No, sir.

"Q. In taking them into the bowels?

"A. No, sir. To an equally susceptible individual the chances of a nearby bacillus having greater vitality are greater so that the disease produced in an equally susceptible individual, the disease produced by a nearby typhoid bacillus would be of more severe type than that produced by bacilli carried some distance.

"Q. But each would produce the typhoid disease?

"A. Yes, sir.

"Q. In an equally susceptible individual?

"A. Yes, sir.

"Q. But one would be of a milder form?

"A. But one would be of milder form.

"Q. Now, I will get you to state if there is any difference medically or bacteriologically from your knowledge as to the virulency of a typhoid disease conveyed in a germ of bacteria that comes from a man sick from a mild form of typhoid and one sick with a virulent disease of typhoid?

"A. No, in passing through the individual their virulency is greatly increased. Bacteriologically that is a thing which is done every day. In order to increase the virulency of a microorganism it is put into the blood of a susceptible animal and its virulency can be greatly increased in that way.

"Q. That would be the effect on a person taking into the system a typhoid bacillus from one sick with mild form of that disease as to whether he would have a mild or severe form?

"A. He would have a severe form if bacteria were to be put into a susceptible individual; coming from a mild case or

severe case it would not matter very much, the virulency would be heightened by the transit through the individual.

"Q. Provided they were equally susceptible in both cases?

"A. Yes, sir.

"Q. General Hamlin asked you a question yesterday if it was not fact that the recorded cases showed 50 miles or less as the distance that bacilli traveled through water and produce disease. I will ask you to show why the records show that to be more or less the fact?

"A. Because of the difficulty of tracing the micro-organism under the complex conditions of modern life. If it were an open river in which the typhoid bacillus were under consideration, the possibility of the river being affected from cases of its banks or other extraneous sources must be weighed, so that to trace an epidemic more than 50 miles is an extremely difficult thing to do, except under such conditions as that of the St. Clair Lake, Detroit epidemic. If the river were covered with a tunnel or running through a tunnel such as the Croton Aqueduct, for a number of miles, then we could say absolutely—for if a typhoid epidemic were to occur in New York, we would feel perfectly confident that no extraneous case of sewage discharge came into the tunnel from any other source than where the aqueduct opened on the watershed. In the Detroit case we had a remarkable instance. Here we had a bed of sewage in a river which had laid there for years and it was suddenly disturbed by dredging and was carried across a lake. It was practically as if in a tunnel, because the sides of the lake were so far away that the one or more cases which might have discharged feces on the periphery of the lake could have no effect. If the material had been carried straight away in a tunnel it could not have been carried more directly to Detroit than it was. That this was the cause of the outbreak of typhoid fever in Detroit Professor Williams has declared on and so reported."

(Ravold's testimony, Vol. 1, pp. 837-949-950-951-952-953.)

The contents of the Chicago Drainage Canal, after entering the DesPlaines river above Bear Trap Dam at Lockport, flow along the DesPlaines river, and the two currents flow into

the Illinois river. From thence they flow to Grafton, a distance of 291 miles from Lockport. The time required for this flow may be safely estimated at from ten to twenty days, the range, of course, depending upon the velocity of the flow of water in the river. There are portions of the stream, namely the upper portion, which flow more rapidly than the lower portions, and some water presumably reaches Grafton quicker than indicated by the average above mentioned. The dilution of the Chicago sewage, as it flows from Lockport to Grafton, by the waters of the Illinois river and tributaries, is a very variable proposition. At times the dilution of the contents of the Chicago Drainage Canal by the flow of the Illinois river and its tributaries is very considerable. At other times the flow of the Chicago Drainage Canal exceeds the flow of the Illinois river, this being particularly true in its upper reaches; consequently there results at times a dilution of the Chicago sewage by the waters of the Illinois river, and other times a dilution of the Illinois river by the contents of the Chicago Drainage Canal. Dilution at best does not destroy disease germs or infectious matter. Its effect is to minimize the danger to those who may drink of the water so infected. One effect of the dilution existing in the Illinois river at low stages is to bring to Grafton more quickly than would otherwise be the case injurious matter entering the Illinois at points along the route of its flow, and also entering from Chicago and cities and towns located upon its tributaries. Nor can it be said that the locks and dams found along the course of the Illinois river are sufficient under any circumstances to arrest the progress of pathogenic bacteria down stream. While it is true that in a great many places during certain times of the year deposits of sediment may take place for a considerable time, and pathogenic bacteria suspended in the water may be carried downward and lodged upon the bed of the river, but this does not mean their permanent elimination and removal from the water; the reason is that as they reach the bottom and lie on the bed of the stream they are disturbed from time to time, caused by moderate rains or by the passage of boats, the action of the winds or the like. The resulting disturbances cause the bacteria to leave the bed of the stream in

which they may rest for some time, bringing about their return into the flowing water. In this way the germs of disease pass from the Chicago Drainage Canal at Lockport to the mouth of the Illinois river at Grafton, there being no question but what the typhoid fever germs do not disappear from the river entirely, and while some of them may submit to the processes of sedimentation in the flowing stream and become deposited in the bed, yet they are able to live there for weeks and months, so that such conditions may arise as will render the Illinois river at Grafton richer in typhoid fever germs derived from the Sanitary District of Chicago coming through the Drainage Canal than is that portion of the water drawn from the Drainage Canal as it flows over Bear Trap Dam. So that in view of all the facts and conditions as found today, the sewage from the Sanitary District of Chicago pollutes and infects the water of the Mississippi river along the shore, and especially at the Chain of Rocks Intake Tower of the St. Louis Waterworks to such an extent as to render the Mississippi river water less safe for drinking purposes than it was prior to the opening of the canal on January 17th, 1900. (Fuller's testimony, Vol. 3, pp. 2617 to 2621, inclusive; Fuller's cross examination, Vol. 3, p. 2640-1; Hazen's testimony, Vol. 3, pp. 2799, 2801-2. Hazen's cross-examination, Vol. 3, page 2810.)

After making almost innumerable chemical examinations of the water of the respective rivers and studying the topography of the country and all of the physical surroundings appertaining to the question of infected water, and having made examinations of the water supply of the city of St. Louis prior to and since the opening of the Chicago Drainage Canal, Prof. Teichmann expressed it as his opinion that the water supply of the city of St. Louis is more polluted now by reason of the opening of the Chicago Drainage Canal and in the flow of the sewage from the city of Chicago than it was prior thereto. (Teichman's evidence, Vol. 2, page 1307.)

Prof. Sedgwick, in his testimony, stated in this connection, as follows:

"In my opinion as an expert on water supplies for cities and towns, the water of the Mississippi river west of the center of the main channel below the mouth of the Illinois river down to the intake tower of the St. Louis Water Works at the Chain of Rocks is decidedly less valuable for drinking purposes, and more likely to carry water borne diseases, such as typhoid fever and cholera, now than it was before the sewage from the Sanitary District of Chicago was run into the drainage canal and through it into the Illinois river. (Vol. 3, page 2194.)"

Prof. Sedgwick further says that the addition of such a volume of liquid as passes through the drainage canal must materially quicken the flow of the Illinois river, and must therefore hinder the effect of sedimentation by shortening the time required for infectious germs to pass through the river, and by interfering with their detention, and aggravating the danger of their arrival at the mouth of the river. I should like to say here that the time allowed in all these matters is very important, so that any quickening of the flow is a grave consideration. It is not so much the distance as the time, that is the basis of self-purification of streams.

When this is taken into consideration with the further statement made by Prof. Sedgwick, borne out by the evidence in the case, that at times the water passing the drainage canal represents five-sixths of the water flowing down the Illinois river, the conclusions arrived at by Prof. Sedgwick cannot be controverted. In addition to the foregoing, the effect of the added volume of water and increased flow of the river would shorten the time for carrying the sewage from Joliet, Peoria and other towns on the Illinois river to the Mississippi at Grafton, and at the Chain of Rocks. (Sedgwick's testimony, Vol. 3, page 2196.)

The increase made in the speed of the current in the Illinois river by the addition of the water from the drainage canal has the effect of increasing typhoid and liability to typhoid and other water borne diseases on the part of the inhabitants of the State of Missouri using the water of the Mississippi for drinking purposes below the mouth of the Illinois river. (Sedgwick's testimony, Vol. 3, page 2196.)

And speaking generally, such conditions as have existed since the opening of the drainage canal and the discharge of sewage from Chicago renders the water of the Mississippi river at St. Louis unfit for drinking purposes and domestic use. (Sedgwick's evidence, Vol. 3, pages 2196-7.)

The water of the Illinois river, since the opening of the drainage canal, as it enters the Mississippi river, is one which should not be used for drinking purposes, and the fact that the pollution of the Illinois river is contributed to largely by the Chicago Sanitary District and from the large amount of typhoid fever in said district, the effect of the time interval, dilution and sedimentation occurring between Chicago and Grafton would not, emphatically not, be sufficient—be such as to render the water as it enters the Mississippi, free at all times from producing water borne diseases to those who drink it. This for the reason that such processes of self-purification, including sedimentation and dilution, as would take place in the Illinois river, and above to Chicago would be inadequate to insure at all times and seasons a complete removal of infectious material. (Sedgwick's testimony, Vol. 3, pages 2199 and 2200.)

Prof. Sedgwick made a careful study of the typhoid fever statistics of the city of St. Louis with the general result that during the period of fifteen years prior to January 1st, 1900, the typhoid fever death rate in St. Louis had not in general been above that of some cities considered of good repute. During the period following the removal of the intake from Bissell's Point to the Chain of Rocks, the typhoid death rate of St. Louis was remarkably good, much lower than it had been and lower for example, than the death rate of the city of Boston for the same period. Beginning with the first of January, 1900, there has been a marked annual increase in the typhoid death rate in St. Louis, so that it has during that period not only been higher than during the previous period of five years, but has been higher than at any time in its previous history since 1885, and very much higher than the death rate of the city of Boston, with which previously it compared very favorably.

The increase since January, 1900, in the annual mortality from typhoid fever as compared with the preceding five years, has been 77 per cent. It might be well to state here that the water supply of Boston is considered a fairly good supply and ranks amongst the water supplies of the country as a good water supply, thus showing clearly, when taking into consideration the fact that there was no increase in typhoid in the principal towns and cities in Missouri on the Mississippi and Illinois rivers, exclusive of Chicago, that the opening of the Drainage Canal has caused the death rate to change from an annual decrease of 26 per cent to an increase of 77 per cent, comparing the conditions for the years immediately before the opening of the canal with those immediately after the opening of the canal. (Sedgwick's testimony, Vol. 3, 2202-2203.)

Since the opening of the Chicago Drainage Canal the water in the Illinois river has become much more infected by disease producing bacteria than prior thereto, and has been rendered less safe, and consequently has produced an unsanitary effect upon the waters of the Mississippi river below Grafton and at St. Louis. (Sedgwick's testimony, Vol. 3, pp. 2222-3-4-5 and 2253. See also Whipple's testimony, Vol. 3, pp. 2208, 2137, 2149, 2150, 2152, 2155.)

In this connection Mr. Gardner Williams stated as follows:

"I should say that the evidence of the typhoid fever statistics of the city of St. Louis for the period mentioned from 1895 to 1899, indicate that the water supply of St. Louis is not ideal, nevertheless it would compare favorably with that of a very large number of American cities, and generally speaking it would entitle the St. Louis water supply to rate with about the second rate of water supplies as water supply experts usually consider them, and considering the evidence of typhoid statistics of the city of St. Louis since the beginning of 1900 it appears that up to near the end of January the water supply of St. Louis during the year 1900 must have been about as good as formerly, but that about that time there appears to be considerable infection, which has continued to increase from time

to time since, with the result that typhoid statistics show the infection during the years 1901 and 1902 to have been nearly twice as great as existed on the average from 1895 to 1899, inclusive, and that the rank of the water supply of the city of St. Louis has materially dropped, judged by the standard of water supplies.

"I have examined the record of typhoid fever in cities on the Mississippi, Illinois and Missouri rivers outside of the sanitary district of the city of Chicago, and I am unable to find anything in those statistics which would account for the large increase in typhoid fever in St. Louis since the 17th day of January, 1900. Basing my opinion on the facts brought out by our extended examination of the conditions which seem to bear on the questions involved, it is my judgment that the discharge of sewage from the sanitary district of Chicago into the Mississippi by means of the Chicago Drainage Canal, the Des Plaines river and Illinois is attributable to the major part of the increase of typhoid fever revealed by the typhoid fever statistics in the city of St. Louis since the beginning of 1900, as compared with from 1895 to 1899, inclusive." (Williams' testimony, Vol. 3, pp. 2462, 2463 and 2473.)

In reference to the question as to whether typhoid bacilli passed from Chicago to St. Louis, Mr. Whipple stated the following:

"From what I know about the life of typhoid fever bacillus in the water, and from my knowledge of the conditions which exist between the Chicago Drainage Canal and the intake of the water works at St. Louis at the Chain of Rocks, it is my opinion that typhoid fever germs existing in the sewage of Chicago will survive the passage down the Chicago Drainage Canal to the intake tower of the St. Louis Water Works at the Chain of Rocks under existing conditions. About one month ago I made a personal inspection of the Chicago river, and Chicago Drainage Canal, and Desplaines river as far as Joliet, and saw the point where the Chicago river naturally drains into Lake Michigan, saw the north branch of the Chicago river, the south branch of the Chicago river and the south fork of the south branch, and

what I believe is called the west fork of the south branch of the Chicago river, and saw the point where the Chicago Drainage Canal begins and its terminus at Lockport. I saw the Bear Trap Dam at that point and saw the Illinois and Michigan canal at that point. I noticed the place where it discharged into the Des-Plaines river and saw the DesPlaines river at Joliet, and the dam at that place. It is my belief that, assuming the sewage and lake water passing from the Chicago river to the drainage canal reaches the Mississippi river at the Chain of Rocks in ten and a half days, typhoid fever germs coming from the sewers of Chicago will survive the passage through the Chicago Drainage Canal, Des Plaines river and Illinois river to St. Louis. I believe there are cases on record from my general knowledge of typhoid fever epidemics where epidemics have occurred which showed that they were caused by typhoid fever germs which had remained in water at least ten and a half days prior to the entrance of the water into the service pipes in the community where the epidemic prevailed. (Whipple's testimony, Vol. 2, pages 1996 to 1999, inc.)

"From my knowledge of the existing conditions of the Chicago Drainage Canal, and of the several water courses between the canal and the intake tower of the St. Louis water works at the Chain of Rocks, there exists no work of artificial construction which insures the prevention of typhoid fever germs which may enter the Chicago Drainage Canal from reaching the intake of the St. Louis water works at the Chain of Rocks." (Whipple's testimony, Vol. 2, page 2002.)

Prof. Sedgwick, in Vol. 3, page 2314, in this connection, says:

"I am ready to assert my conviction, my positive conviction, that typhoid bacilli may and do live to make a journey from Chicago to St. Louis. Based on the whole chain of evidence which I have in my possession regarding the sanitary history of Chicago, the character of water used to dilute the sewage of the city of Chicago, the character of the Illinois river, especially being subject to floods, the character of the Mississippi river into which the Illinois river enters, and with which the Illinois

freely mixes, is that such germs may be carried alive and virulent from the people of Chicago to the intake tower of the St. Louis water works, and further upon the vital statistics of St. Louis having studied and compared them with the vital statistics of other communities."

Under existing circumstances and conditions from Lockport to Grafton, whether these conditions be taken separately or collectively, they are not sufficient to prevent the polluting and infectious material from coming from the Sanitary District of Chicago down the Illinois river and entering the Mississippi at Grafton, and the distance from Grafton to St. Louis of about 28 miles, and the time required for the water to flow from Grafton to St. Louis but one day, the waters of the Illinois river will become thoroughly mixed with the waters of the Mississippi by the time the Chain of Rocks is reached. (Fuller's testimony, Vol. 3, page 2621.)

Considering the greater concentration of the polluted matter contained in the Chicago river prior to the opening of the Drainage Canal than there is now in the main channel of the Drainage Canal, conditions are less favorable in the Chicago river since the opening of the canal than they were prior thereto. This is based upon the proposition that the slower the flow the less dilution and the more organic matter the more saprophytes, consequently the sooner the death of pathogenic bacteria. (See Zeit's testimony, Vol. 5, pp. 4510-11-52-53-54.)

The water of Lake Michigan, according to the analyses of Prof. Palmer and others, contains much less total organic nitrogen than is found in the waters of the Illinois river at Kampsville or at Grafton. It is a known fact that the waters of Lake Michigan, when consumed by the people of Chicago, have produced extraordinary results in typhoid fever. Considering that the flow of the stream from Chicago to Kampsville and Grafton is within the life limit of the typhoid germ, there is nothing in the science of bacteriology or chemistry as applied to streams examined which disputes the idea that typhoid bacilli will not pass from Chicago down the Illinois river to Kampsville, Grafton and St. Louis. When we take into consideration the fact

that there is more nitrogenous substance contained in the waters of the Illinois river than in Lake Michigan, it is difficult to avoid the conclusion that a great portion of the increase of typhoid fever in St. Louis is due to the Chicago sewage. In this connection Prof. Palmer stated:

"Whether the organic nitrogen contained in the water of Lake Michigan analyzed by me did or did not contain the micro-organisms which produce typhoid fever, I do not know, but assuming it to have been present therein, it is my opinion that there is nothing in my sanitary chemical analysis of the waters of the Illinois river at Kampsville which has determined whether or not a bacillus of typhoid fever was contained in that water. Now, assuming that there was the same relation between the numbers or amounts of micro-organisms in the waters of Lake Michigan and the Illinois river at Kampsville, then it is my opinion that the relation the numbers of said micro-organisms would have to each other would be similar to the proportions of the total nitrogenous organic matter in each of these two waters."

The average proportion of total organic nitrogen contained in the waters of Lake Michigan analyzed and testified to by Prof. Palmer for the year 1897 was .268 parts per million; for the year 1898 .202 parts per million; for the year 1899 .188 parts per million, and for the year 1900 .186 parts per million; the average for the years named being .211 parts per million. The average proportion of total organic nitrogen contained in the waters of the Illinois river at Kampsville in 1897 was 1.204; for the year 1898 1.018; for the year 1899 1.129; the average for the three years being 1.157. The average total organic nitrogen contained in the waters of the Illinois river at Kampsville during 1900 was .904, and 1901 was .999; the average for the two years was .951.

The relation the proportion of total organic nitrogen found in the waters of Lake Michigan for the four years, 1897 to 1901, inclusive, bears to the proportion found in the waters of the Illinois at Kampsville for the period 1897 to 1899, inclusive, is as one to five; in other words, one for Lake Michigan and five for the waters of the Illinois at Kampsville.

The proportions of organic nitrogen found by Prof. Palmer in the waters of Lake Michigan for the year 1900 and those found in the waters of the Illinois river at Kampsville for the same year were one for the waters of Lake Michigan and 4.86 for the waters at Kampsville.

Assuming that in the year 1899 there were a large number of cases of typhoid fever in Chicago, and that in the year 1900 there were a like number of cases of typhoid fever in that city, and assuming that in the year 1899 the discharges of the dejecta of those patients in Chicago reached the intake crib and were present in the water analyzed; and assuming that for the year 1900 the typhoid dejecta from the patients in the city of Chicago were discharged into the sewers of the city and thence into the Chicago river, the drainage canal, and through the drainage canal discharged into the Illinois river, there is nothing in the science of chemistry or in the chemical analyses which have been made of the waters of the Illinois river at Kampsville which discloses that these typhoid fever organisms so discharged at Chicago did not reach and are not contained in the organic matter in the waters of the Illinois river at Kampsville. (Palmer's testimony, Vol. 6, pp. 5655-6-7-8.) (E. G. Smith's testimony, Vol. 7, pp. 6828-9.)

Conditions on the Illinois river, prior to the opening of the canal, being such that there was practically no current, with a green scum forming upon the surface of the water during the greater part of the year, while since the opening there has been a decided current and no scum, assuming that the waters of the river both prior and before the opening were infected by typhoid fever dejecta and other contaminating products, the conditions obtaining before the opening of the canal would be much more favorable to the destruction of typhoid fever bacilli than those conditions which obtained subsequent to the opening of the canal. (Mason's testimony, Vol. 7, 6965.)

Before the drainage canal was opened the typhoid death rate in the city of St. Louis was below the average of the experience of other cities of similar size in the United States, and

the city was recognized as having a reasonably good water supply, the death rate from typhoid fever being about 20.4 per 100,000 poulation. (See Fuller's testimony, Vol. 3, pp. 2608-9.)

It being an undisputed fact that typhoid fever germs are deposited in the Drainage Canal in Chicago through the sewers at Chicago, and it must therefore be shown by the testimony in the case beyond the possibility of doubt and with absolute assurance that such germs perish before reaching the intake of the St. Louis water supply at the Chain of Rocks.

The essential inquiry then is, how far may this particular germ travel in a running stream before losing its vitality. According to the experiments made by Dr. Ravold, it is shown to live in the laboratory under conditions which approach, as far as possible, those existing in the running stream, from 15 to 30 days. The distance that it may be conveyed therefore depends upon the longevity of the germ, together with the velocity of the stream flows.

In other words, as expressed by Dr. Ravold in his testimony, longevity and speed of the water constitute the prime factors in determining how far typhois bacilli may be carried by the current of the stream.

(Dr. Ravold's testimony, printed record, volume 1, pages 480 and 792.)

It is a fact, as shown by the testimony, that the water from Lake Michigan flows to St. Louis within the life time of the Bacilli Typhosus. In drawing conclusions and passing judgment upon the stream flow and the longevity of the germ, Dr. Ravold in his testimony spoke in no uncertain tone as to the ability of these germs reaching St. Louis from Chicago. He testified substantially as follows:

"Q. Now state in your opinion and from the examinations that you have made of the water in the DesPlaines river, the Illinois and Mississippi rivers, how long typhoid bacilli would live in the running water in going from Chicago to St. Louis?

A. Well, taking conclusions from the laboratory experiments, we find that bacteria will live from four days to as high as twenty-one days.

Q. That is in a flask?

A. In the laboratory flask, in living non-sterilized waters. Passing conclusion on them I am inclined to believe that the bacilli would live much longer in a running stream in living water than that period.

Q. How much longer?

A. Anywhere from fifteen to thirty days, and that would be a very small limitation.

Q. A conservative estimate?

A. A very conservative estimate.

Q. Now you spoke in reference to the period in which the bacilli would be vitalized and capable of producing disease when injected in the human system.

A. Yes, sir.

Q. You are speaking of the typhoid bacillus?

A. Typhoid Bacillus.

Q. Doctor, assuming that it requires the water 17 days to run from the sewerage openings at Chicago down the Chicago river to the canal, the canal to the DesPlaines river, the Des-Plaines river to the Illinois river and thence to the Mississippi river; the intake at the Chain of Rocks, and thence into the reservoir, when in two days thereafter it is distributed and used by the people of St. Louis, what would you say with reference to typhoid bacillus discharged in the Chicago Drainage Canal through the sewerage system of Chicago, finding its way into the water distributed to the people of St. Louis, as above described, and be sufficiently vitalized to produce disease, and taking into consideration your actual experiments with the typhoid bacilli in connection with the water in the various streams through which it would run?

A. Now the time consumed in traveling from Chicago of the sewerage would be seventeen days in the river to the intake and three days thereafter before being distributed to the people —twenty days. I think it highly probable from my experiments that typhoid bacilli discharged by the sewerage system of Chicago into the Drainage Canal would live and retain its vitality in the meanwhile entering the intake of the St. Louis water

works, and be distributed to the user of the water to be sufficiently vitalized to cause disease in a susceptible person.

Q. Now in connection with your answer to the last question and taking into consideration the great number of typhoid bacilli that come from the patient afflicted with the disease, and all other information that you possess on the subject—from the examination that you have made, what would you say with reference to the typhoid bacillus from Chicago finding its way into the reservoir and water supply of St. Louis?

A. Well, as I said before, I think it is highly probable that they could be carried into the intake and reservoir of the St. Louis water supply and retain their vitality meanwhile.

Q. Would they be sufficiently vitalized when found in the water supply of St. Louis to produce disease?

A. I think so. I would not like to try the experiment upon myself.

Q. State the length of time in your opinion typhoid bacilli would live in the waters running between the city of Chicago and the city of St. Louis, and being sufficiently vitalized when arriving in the water supply of the city of St. Louis to produce disease?

A. I said fifteen to thirty days. I thought I had answered that question. That is a conservative estimate.

(Dr. Ravold's testimony, printed record, volume 1, pages 807, 808, 809.)

On another point Dr. Ravold testified in this connection, as follows:

Q. Now, doctor, having carried out these experiments, having treated typhoid fever for twenty years, having been a Professor of Hygiene in the Washington University as a practical bacteriologist, I will ask you in your judgment if typhoid bacillus, coming from the out-falls of the Chicago sewers into the Chicago river and carried into the canal, could come into the Intake Tower of the St. Louis water works still retaining its vitality?

A. That will depend on the time that it takes the water to come from Chicago to St. Louis.

Q. Well, considering your knowledge of the flow?

A. Basing my conclusions upon the experiments that I have carried out and showing that the Mississippi and Illinois river water comes into the intake of the St. Louis water works, I believe that it is highly probably that a typhoid bacillus can live and be carried by the water from the Chicago sewers into the intake of the St. Louis water works, especially in the high water conditions of the Illinois river.

Q. Now, Doctor, does the speed of the water effect the life of the bacillus typhosus or typhoid bacillus. In other words, does the rapidity of the current tend to destroy the typhoid bacteria?

A. No, sir.

Q. Does the force of the water into which typhoid bacillus may be put effect in any manner its vitality?

A. No, does not kill it.

(Dr. Ravold's testimony, printed record, volume 1, pages 787-788.)

Again Dr. Ravold testified substantially on typhoid bacillus, as follows:

Q. Now from your knowledge as a bacteriologist and from the knowledge you have of the Chicago Drainage Canal, the DesPlaines river, the Illinois river, the Mississippi river and the distances, and the speed of the streams, can you state whether or not when the water is running through the Chicago Canal with the sewerage running into it, bacteria could come from the Drainage Canal into the Mississippi river?

A. Yes, sir. *I think the bacteriological experiments indicate that bacteria discharged by the Drainage Canal, especially in its high stages, are carried into the Mississippi river by way of the Illinois river.*

Q. Well, do you say that as a fact?

A. *Yes, sir.*

Q. Now, from the same state of facts above mentioned, as to the rivers, and the relative geographical location of the Illinois river, the Mississippi river and the Chicago Drainage

Canal, do you say or can you say whether or not the bacteria coming out of the Illinois river and being discharged into the Mississippi river, may or do enter the intake of the St. Louis water works?

A. I think they not only may, but they do, and I base this statement upon the bacteriological investigation that has been conducted by me from 1897 to the present time, from special experiments that were carried out which lead me to assert that they do from the mixture of the waters that takes place at the intake."

(Dr. Ravold's testimony, printed record, volume 1, pages 799-800.)

In 1894 the intake of the St. Louis water supply was removed from Bissell's Point to Chain of Rocks, and a comparison of the number of deaths from typhoid fever in St. Louis for the year 1895 to 1900, and five years prior thereto, shows a decrease of 125 per cent less since the removal of the intake to the Chain of Rocks than during the five years immediately before.

(Dr. Ravold's testimony, printed record, volume 1, pages 760.)

For the three years prior to the opening of the Drainage Canal, to wit, 1897, 1898 and 1899, there were 1807 cases and 350 deaths from typhoid fever in St. Louis.

For the three years next following the opening of the Chicago Drainage Canal on January 17th, 1900, there were 3426 cases and 588 deaths in St. Louis, showing an annual increase of 68 per cent.

(Dr. Ravold's testimony, printed record, volume 1, pages 761-762.)

In November, 1899, a few months before the Drainage Canal was opened, there appeared to be an increase of deaths in St. Louis from typhoid fever. This increase is explained by Dr. Ravold as follows:

"I have looked over the health statistics. In 1899 we had a remarkable number of cases in November, 488 cases were re-

ported and 31 deaths. In December, 116 cases and 20 deaths. It was ascertained at this time, in fact I saw the men at work. The river was so low in 1899 that it was feared by the Water Commissioner that the lowest gate in the Intake Tower would not be low enough to admit enough water for the pumps, so a coffer dam was built about the intake and men put to work breaking a hole through the tower for the purpose of putting in a gate. The work at the intake out in the river on the east side of the tower as low down as they could go, so as to have a very low gate for low water periods. They went down to the bottom of the river and stirred things up pretty well. They worked at the bed of the river and stirred up the mud. The stirring up of the silt and mud in the bottom of the river where it had settled at the bottom of the Intake Tower had the effect to stir up any typhoid or pathogenic bacteria in the water. At the same time there was dredging going on in the Illinois river at Kampsville. They were digging out a channel for boats, digging out the bottom of the bed of the river. This of course caused such large quantities of mud and silt to be abstracted from its resting place at the bottom of the river and carried off down the stream."

(Printed record, volume 1, pages 764-765.)

With reference to the highest number of typhoid fever cases recorded and the lowest number recorded in the year 1900, there is a relation existing between the percentage of Mississippi river water as shown by this map, going into the intake of the St. Louis water works.

In the early part of the year from February 6th, 1900, the quantity of water estimated by total solids in the Mississippi river increased at the intake and reached 100 per cent on February 8th, 1900, or 21 days after the Drainage Canal was opened.

The period of incubation of typhoid germ is from six days to three weeks.

There is also a relation, as shown by the map, between the rise in the number of typhoid fever cases at St. Louis and the rise in the percentage of the water of the Mississippi river entering the intake at this particular time.

During this period 100 per cent of Mississippi river water entered the intake, it not being mixed with Missouri river water, and on March 3rd, 1900, there was an increase in the typhoid fever cases. From February 8th to March 3rd, 23 days, it was then that the deaths from typhoid fever increased to assert itself and continued until March 17th. The Missouri river in the meantime having increased in volume, the amount of the Mississippi river water entering the intake March 17th having fallen to 12 per cent, so that there was a gradual increase of typhoid fever in St. Louis from March 3rd to March 17th, and from March 24th to April 7th, corresponding with the percentage of Missouri and Mississippi river water entering intake during the period from February 8th, when it reached 100 per cent, and from that day gradually fell until on the 15th of February it was only 12 per cent.

(Printed record, volume 1, pages 439-444.)

It will be well to note that this period was immediately after the opening of the Drainage Canal.

The evidence shows that typhoid fever increased with the water of the Mississippi river mixing with the water of the Illinois river flowing into the intake.

(Printed record, volume 1, page 447.)

Typhoid fever conditions in St. Louis in the month of March, 1900, became almost epidemic. Within the incubation period after the opening of the canal of the passage of the water from Chicago to St. Louis, the typhoid fever death rate ran up very rapidly, and in March 117 cases were reported and 16 deaths. A phenomena that never had occurred in the existence of St. Louis, Missouri. No such flare of typhoid in March has ever been recorded in the history of the city, as followed this mixture of the waters of the Illinois and the Mississippi river at the intake.

(Printed record, volume 1, page 837.)

We have seen that the percentage of the Mississippi river water entering the intake during the month of March, 1900,

reached as high as 100 per cent, and during the period from the opening of the canal until the 28th of May, the percentage of the Mississippi river water entering the intake rose and fell from May 28th until June 29th, when it again arose to 39 per cent. On August 31st the percentage again reaches 50 per cent. During all of the periods enumerated the number of typhoid cases at St. Louis was increasing with the increase of the Mississippi river water entering the intake at low stages of the river.

This comparison is true throughout the entire period of this investigation.

(Dr. Ravold's testimony, printed record, volume 1, pages 446-447.)

The effect of the increase quantity of Mississippi river water entering intake at St. Louis increased the typhoid fever deaths at St. Louis for the year 1900 over that of 1899, as shown by a comparison of the deaths from this disease in the respective months of the two years.

(Dr. Ravold's testimony, printed record, volume 1, pages 448.)

(See also Complainant's exhibit No. 10.)

The typhoid mortality records of the principal cities and towns on the Illinois, Mississippi and Missouri river watersheds were obtained where it was possible to do so, from 1893 to 1902, inclusive. This investigation disclosed no permanent increase in any locality so as to account for the increased number of deaths in St. Louis since January, 1900. This investigation resulted in the following data being obtained:

Deaths reported from typhoid fever in cities lying tributary to the Illinois river, exclusive of Chicago.

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
Peoria				13	18	18	12	33	15	18
Bloomington	12	14	15	9	10	10	9	15	9	15
Springfield										
Ottawa	2	5	2	2	4	4	3	3	5	2
Decatur	5	7	2	1	7	5	7	11	5	4

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
Joliet	12	14	*	12	12	15	15	13	13	21
Pekin										
Elgin	5	3	5	14	8	4	5	15	15	8
Aurora	6	12	19	10	5	10	4	17	11	2
Havana										
Totals	45	62	45	66	56	66	55	129	85	82

*No record.

Deaths reported from typhoid fever in the following cities, according to the public records:

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
St. Paul	51	32	38	37	22	43	30	36	24	23
Minneapolis	134	107	88	60	148	86	71	79	121	66
Red Wing, Minn.	5	2	2	3	2	4	3	3	2	3
Winona, Minn.	2	2	1	2	2	2	5	5	1	4
La Crosse, Wis.	15	2	5	0	3	8	7	7	5	4
Dubuque, Ia.	6	6	12	8	12	10	12	7	8	10
Clinton, Ia.	10	5	3	7	5	7	7	10	12	5
Rock Island, Ill.	15	13	3	13	15	15	10	14	28	5
Moline, Ill.	7	9	8	11	3	5	20	22	16	7
Davenport, Ia.	5	6	4	3	5	2	12	14	11	11
Muscatine, Ia.	4	8	5	5	2	25	2	13	8	5
Burlington, Ia.	8	10	8	13	3	4	8	13	12	11
Fort Madison, Ia.										
Keokuk, Ia.	8	14	3	3	7	10	9	10	4	7
Quincy, Ill.	22	33	24	13	15	6	7	9	12	18
Hannibal, Mo.	7	7	6	8	10	8	4	3	3	2
Louisiana, Mo.										
Des Moines.	22	29	30	14	20	17	13	7	22	21
Yearly totals	321	285	240	200	257	237	217	261	291	210

Deaths reported from typhoid in cities on the Missouri river watershed:

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
Lincoln, Neb.	33	21	23	15	14	12	13	4	13	10
Omaha	22	40	29	18	22	32	26	24	23	20
Council Bluffs.	5	7	6	8	8	6	8	11	6	8

St. Joseph, Mo.	20	22	31	19	15	19	37	20	12	13
St. Charles, Mo.							22	5	6	14
Kansas City, Mo.	59	37	34	29	38	49	52	49	58	58
Jefferson City.										16(?)
Totals	139	127	123	89	97	118	158	113	118	139

Total number of deaths reported from typhoid fever in cities lying tributary to the Mississippi, Missouri and Illinois rivers, respectively:

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
Mississippi	321	285	240	200	257	237	217	261	291	210
Missouri	139	127	123	89	97	118	158	113	118	139
Illinois	45	62	45	65	56	66	55	129	85	82
Total	505	474	408	354	410	411	430	503	494	431

DEATHS IN CHICAGO AND ST. LOUIS.

Chicago

1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
1008	1997	1489	670	491	518	751	437	636	442	339	509	801

St. Louis

1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
277	160	488	215	178	106	106	125	95	130	168	198	222

(Record, Vol. 7, pp. 6901-3.)

The cities of St. Charles and Jefferson City on the Missouri river watershed; Springfield, Pekin and Havanna on the Illinois, and Fort Madison, Louisiana on the Mississippi should not be considered for the reason that full and complete data could not be obtained as to them.

The foregoing affords no reason, excuse or cause for the increase at St. Louis subsequent to January, 1900.

20.

THE DAMS IN THE ILLINOIS RIVER AND THEIR EFFECT.

There are five dams constructed across the Illinois river. Three were built by the State of Illinois, and two by the United States Government for the purpose of aiding navigation. Before the drainage canal was opened the water behind the dams for a distance of fifty or sixty miles would, during the greater part of the year, obtain a quiescent state, which materially aided the self-purification of the water in the stream, inasmuch as stagnant water purifies itself more rapidly than running water. Sedimentation was added, and every possible advantage given the river to purify itself. Since the opening of the drainage canal the dams have been of little or no service in this regard. As the testimony shows, the water flows down the river and over the dams in a constant and continuous current, and while these dams may have furnished sedimentation basins, so to speak, before the canal was opened, and may be regarded to some extent as aiding sedimentation today, yet the continual changing in the flow of the stream and body of water picks up sediment and carries it over the dams and on down the river. Since the opening of the canal the water is known to flow continuously and requires only an average time of ten to fifteen days to pass from the sewers of Chicago to the city of St. Louis. (Williams' testimony, Vol. 3, pp. 3324 to 3326.)

So far as the dams produce slack water or quiescence, self-purification is favored, but if sedimentation or sludge is allowed to remain in the stream and only removed artificially, the chances are good, as experience shows, that in freshets it will be returned to the stream and again become a part of it and travel with it and produce trouble below. This has been the experience of cities such as Newburyport, Lowell and Lawrence. (Sedgwick's testimony, Vol. 3, pp. 2218-19.)

The general effect of dams is to hold back the water and produce slack water basins, especially when the dams are high enough to check the flow entirely, or essentially. And any checking of the flow or slowing of the stream, other things being equal, favors sedimentation and the disappearance, from the waters, of the infectious material. "The sanitary significance of this is, as I have already stated, extremely interesting and important. The carrying down of the germs of infectious diseases and the longer or shorter detention of them in the sediment in the first place removes them from the moving water, or tends to remove them, and in the second place by detaining them gives them an opportunity to die out more or less. These factors of sedimentation and storage are, in my judgment, the principal factors in the so-called self-purification of streams. On the other hand, it must be carefully kept in mind that streams are subject to scouring more or less frequently and that the disappearance of infectious materials is not necessarily their destruction. A considerable increase in the flow of such a stream as the Illinois river must tend to favor the return to the stream of some of the materials which have been previously deposited in it. The wind, even, may cause sediment to be stirred up, especially where the water is shallow. It is a well-known fact that Lake Erie is so easily disturbed by winds as to bring up sand from the bottom and interfere with the use of the water at Buffalo for drinking purposes. (Williams' testimony, Vol. 3, page 2386.)

21.

POPULATION OF THE WATERSHEDS OF THE RESPECTIVE RIVERS WITH, AND, EXCLUSIVE OF THE POPULATION OF THE SANITARY DISTRICT OF CHICAGO, TOGETHER WITH THE AREA OF THE DRAINAGE BASINS OF EACH.

According to the report of Jacob A. Harmon, found in the report of the Illinois State Board of Health on the sanitary condition of the Illinois river, and its tributaries in 1901, at page

119, it is stated that the total rural population of the Illinois drainage basin in the year 1900 was 893,723, the urban population of the Illinois river, exclusive of the city of Chicago, in 1900 was 616,664, the area of the Illinois river basin being 27,914 square miles. (Whipple's testimony, Vol. 3, pp. 2131-2.)

Considering cities having a population of 25,000 or over, according to the census of 1890, the increase of population naturally resident upon the watershed of the Mississippi river above the Chain of Rocks caused by the addition to the population of the Sanitary District of Chicago, speaking generally, has been about doubled. If we consider the population of cities having more than 4,000 population situated upon the watersheds of the Missouri river, Mississippi river and Illinois river, above the Chain of Rocks, but not including the population of Chicago, and if we add to this the population of Chicago, the increased population for the entire watershed of the Mississippi above the Chain of Rocks would be about 63 per cent. In that connection it would be well to state as a general proposition that it is customary for sanitarians to consider that the amount of sewage pollution in streams may be approximately estimated by taking the total population of towns on its watershed having a population of four thousand inhabitants or over.

(Whipple's testimony, Vol. 2, pages 1988-89-90.)

As a general rule, the urban population is very much more dangerous than rural population; expressed in figures, it would probably be fair to say that the urban population was at least ten times as dangerous as the rural. The reason for this is that urban populations are more often sewered, and when not sewered are more often upon streams, while the rural population is very often remote from streams, almost always without sewers, and even if the same infection occurs in a rural family as in an urban family the chances of keeping that infection within the family and on the place are far greater than they are in the case of an urban population. It is, therefore, obvious, as a general proposition, that the rural population is of comparatively little importance in this respect, it being the urban popu-

lation that we have chiefly to consider. By the opening of the drainage canal the sewage from the urban population tributary to the watersheds of the Mississippi river as it flows to the intake tower of the St. Louis Waterworks, has been increased about 63 per cent. The urban population on the watershed of the Mississippi river and its tributaries above the intake of the St. Louis Waterworks, exclusive of the Sanitary District of Chicago, based upon the population of towns having more than four thousand inhabitants, is 2,695,782; in other words, this population may be divided as follows: On the watershed of the Missouri river, 1,090,832; the upper Mississippi river, above the mouth of the Illinois, 1,219,645; upon the Illinois river, exclusive of Chicago, 385,305, making the total, as above stated, 2,695,782. Sedgwick's testimony, Vol. 3, pages 2235-6.)

In answer to the question as to whether he had made an estimate of the approximate number of persons sewering into the Mississippi river, exclusive of the Sanitary District of Chicago, Mr. Fuller (Vol 3, p. 2616) made the following answer:

"I have looked into this matter, and in round numbers place the figure for those people who sewer directly into the Mississippi and its branches and tributaries above the St. Louis Water Works and exclusive of the Sanitary District, at about 2,700,000. This figure is based upon a separation, on an average of the sewage contributing population from the rural population by taking towns of 4,000 and over as representing those who have sewerage systems and contribute sewage directly to the water courses. Some of the towns of more than 4,000 population are undoubtedly not provided fully with sewerage facilities. On the other hand, there are quite a number of towns of less than 4,000 population which in a limited measure do have water works, and do have some sewerage. Looking at this question as a practical proposition, it is my judgment that the amount of the sewage contributing population in towns of less than 4,000 inhabitants no more than off-sets in the aggregate the amount of population in the cities larger than 4,000 inhabitants which do not have sewers. It is a fact well known among practical water works and sewerage people that the number of miles of

water-mains in a town ordinarily exceeds to a considerable degree the number of miles of sewer lines. In making this statement as to the number of people in the aggregate sewering into the Mississippi river above the Chain of Rocks intake, I include of course the Missouri river and the Illinois river, exclusive of the Chicago Sanitary District, as well as the upper Mississippi."

"Q. Mr. Fuller, why did you draw a line at the towns of 4,000 inhabitants for the separation of population contributing pollution directly from those which contribute indirectly?

"A. Well, that matter I took up pretty thoroughly in the last answer I gave, and will state that the basis as described in my last answer is the result of my experience and I think that on the whole it is a reasonable and fair method due to its compensation of the two factors: First, the amount of population in the cities above 4,000 which do not sewer directly into the river, and, secondly, the population of some towns of less than 4,000 which do contribute sewage directly to the water courses.

"Q. Mr. Fuller, what would you estimate to be the percentage of increase in population sewering into the Mississippi river valley above St. Louis, due to the Chicago Drainage Canal bringing sewage of Chicago into the Mississippi river watershed?

"A. In round numbers I estimate an increase of 60 per cent."

TRIBUTARIES OF THE ILLINOIS RIVER AND THEIR SANITARY CONDITION.

The testimony on both sides of the case shows that the sanitary condition of the tributaries of the Illinois river is far better than the sanitary condition of the Illinois river itself, thus going to show that while the immense pollution of infectious material coming down the Illinois river can be accounted for to some extent from the pollution in its tributaries, yet from the fact the tributaries are in better sanitary condition than the river is, we reach the conclusion that the major part of the infectious material is derived from some source other than its tributaries, and, in fact, chemical and bacteriological analyses point to the drain-

age canal as the only source from which this increased pollution can be derived. (Keiser's testimony, Vol. 2, pp. 1140-1-2. Teichmann's testimony, Vol. 2, page 1175.)

22.

THE PHYSICAL CONDITION OF THE ILLINOIS RIVER BEFORE THE CANAL WAS OPENED COMPARED WITH THE CONDITIONS SUBSEQUENT TO THE OPENING OF THE CANAL.

The testimony taken upon the part of the defendants from witnesses who lived upon the Illinois river from its source to its mouth shows beyond question that, prior to the opening of the drainage canal, during the greater portion of the year it was in, what might be called, a septic condition. The current was very slight and at times none at all. Above the respective dams the river assumed the appearance of a green field, being covered with a green scum or algae formation. A canoe or skiff would separate this scum and leave an open path for some distance behind.

The opening of the canal caused an increased volume of water to pass down the river, consequently increased the velocity or speed and carried the nitrogenous matter with the current, which prevents the formation of the algae or scum; in other words, since the opening of the canal the river has not purged itself of the polluting material deposited into it, not having sufficient time to oxidize or destroy the material deposited in it. It has passed out of the Illinois river at its mouth into the Mississippi.

Two miles above the mouth of the river at Grafton, the testimony shows the river to have been in the condition above described. (See Calhoun's testimony, Vol. 3, pp. 2914-16-17.) (See also, D. J. Shoemaker, Vol. 3, pp. 2940-1-2; J. M. Allen, Vol. 3, pp. 2950-1; Wesley Park, Vol. 3, pp. 2955-6; E. Meysenberg, Vol. 3, p. 2960; Daniel Heath, Vol. 3, p. 2960.)

At Hardin, eight miles above Grafton, the same condition obtain as at Grafton. (See testimony of Chas. Flamm, Vol. 4

p. 2995; Nathaniel Bull, Vol. 4, p. 3001; M. E. Fisher, Vol. 4, p. 3001; Albert Park, Vol. 4, p. 3008; Dr. Barry, Vol. 4, p. 3012; George Adderton, Vol. 4, p. 3032.)

So also at Kampsville the same conditions exist. (See C. B. Bakerville, Vol. 4, pp. 3054-5; Ed Heaton, Vol. 4, p. 3060; Thomas Myers, Vol. 4, p. 3064; I. Davidson, Vol. 4, p. 3069; Walter Mapin, Vol. 4, p. 3118.)

C. B. Bakerville, on page 3054 of his cross-examination, Volume 4 of the record, describes the conditions before and after the opening of the canal as follows:

"Q. What is the difference between the current or flow of the river now and what it was prior to the opening of the Chicago Drainage Canal?

"A. Well, we have a good deal changed current.

"Q. How far is it from where this boat is on which we are taking testimony down to the dam?

"A. Something like half a mile.

"Q. This current you speak of continues down on and over the dam, does it not?

"A. Yes, sir.

"Q. What is the stage of the water in the Illinois river at this point as compared with the ordinary stage of the water?

"A. Well, it is some lower right now than it has been for several years; that is, the last two or three years."

It will be observed from this testimony that the water passed in a rapid current over the dam at Kampsville, and what is true with reference to conditions at Kampsville is also true with reference to all of the dams on the river.

Ira Davidson, at page 3069 of his cross-examination, replied as follows:

"Q. What is the stage of the river at Kampsville now as compared with what it has been ordinarily since the opening of the canal in January, 1900?

"A. Well, it is rather low at present.

"Q. Has it been much lower since the opening of the canal than it is now?

"A. Well, year before last, yes, sir.

"Q. That was in the drouth of 1901?

"A. Yes, sir.

"Q. There is a good current in the river now, is there?

"A. Yes, sir.

"Q. A good current here in the river at Kampsville?

"A. Yes, sir.

"Q. That current continues from here to the government dam, about one-half a mile below?

"A. Yes, sir.

"Q. And grows stronger as you go up the river away from the dam?

"A. The farther from the dam you get the stronger the current."

At Gravel Point the same conditions were shown to exist. (See testimony of D. J. Nelson, Vol. 4, p. 3159; Thomas Carter, Vol. 4, p. 3160; George Nelson, Vol. 4, p. 3164; S. D. Thurston, Vol. 4, p. 3165.)

In fact, the same conditions, prior and subsequent to the opening of the canal, existed in Pearls, LaGrange, the lock at LaGrange, Preston, Havanna, Peoria, Pekin, Chillicothe, Henry, LaSalle and other points. (See testimony of J. J. Kerr, Vol. 4, p. 3243; L. W. Gooddell, Vol. 4, p. 3263; O. H. Harpham, Vol. 4, p. 3290.)

The defendants have undertaken to show that the great pollution contained in the Illinois river at Grafton is caused principally by the sewage discharged from the cities of Pekin and Peoria. This, however, is of no consequence when taking into consideration the relative number of people residing at the two places as compared to the population of the Sanitary District of Chicago.

The contention is also made that large quantities of decomposing matter is discharged into the river at these points on account of the distilleries, manufacturing plants and the feeding of cattle. The evidence, however, discloses that at both Pekin and Peoria there are a less number of cattle being fed now than prior to the opening of the Drainage Canal; in other words,

since 1899 the number has decreased materially. According to conditions that existed at Peoria for several years prior to 1900, an average of 25,000 head of cattle were fed per annum, while subsequent to that time the average has fallen to less than 10,000. According to the testimony of Robert D. Clarke, a distiller at Peoria (Vol. 4, p. 3670), not more than one-fifth of the cattle are fed at Peoria now as compared with the conditions existing prior to 1899.

An effort was also made to show that a floating population resided upon the banks of the Illinois river at Peoria, which is stated by counsel for the defendants in some of their hypothetical questions to be about 3,000; yet the fact is, as shown by the testimony of Robert D. Grayson (Vol. 4, p. 3523), this population prior to the opening of the canal, amounted toabout 500, and that since the opening of the canal it has been reduced to about 400, so that the conditions existing upon the Illinois river at Pekin and Peoria have materially improved since January 17th, 1900. So the increase in typhoid fever due to the increased pollution in the river cannot under these circumstances be attributed to Peoria and Pekin. (See testimony of C. F. Barstow, Vol. 4, p. 3587.)

See, in fact, the testimony of all of the witnesses relating to conditions existing upon the Illinois river prior and subsequent to January 17th, 1900.

23.

THE VELOCITY OF THE ILLINOIS RIVER HAS BEEN INCREASED SINCE JANUARY 17TH, 1900, DUE TO THE OPENING AND OPERATION OF THE CHICAGO DRAINAGE CANAL, AND THE INCREASE CONSTITUTES AN ADDED DANGER TO THE PEOPLE OF ST. LOUIS AND MISSOURI.

By the addition of 250,000 to 300,000 cubic feet of water per minute through the canal into the Des Plaines and Illinois rivers, the current of the river has been increased so that the time necessary for pathogenic bacteria to pass from Chicago

to St. Louis has been largely decreased. The addition of such a volume of liquid as passes through the Drainage Canal must necessarily quicken the flow of the Illinois river, and therefore hinder the effective sedimentation, and by this shortening of the time required for the infectious germs to pass through the river, interfering with their detention, aggravates the danger of their arrival at the mouth of the river. It would not only carry the sewage from Chicago to St. Louis with rapidity, but by increasing the flow it would quicken the passage of the sewage or infectious pollution from Peoria and other points to the mouth of the Illinois river and thus mingle them with the waters of the Mississippi river. This increase in the speed of the current of the Illinois river by the added water of the drainage canal would have the effect to increase the liability to typhoid and other water borne diseases on the part of the inhabitants of St. Louis and the State of Missouri using the water of the Mississippi below the mouth of the Illinois river for drinking and domestic purposes. (Sedgwick's testimony, Vol. 3, page 2195.)

So that the Illinois river, polluted and infected by the sewage from the Sanitary District of Chicago since the opening of the Drainage Canal by being forced down the river on account of the increased volume of water coming from Lake Michigan has rendered less safe the water supply of the city of St. Louis, drawn at the intake tower at the Chain of Rocks, than it was prior to January 17th, 1900. (Sedgwick's testimony, Vol. 3, page 2224.)

24.

THE INCREASE IN TYPHOID FEVER IN ST. LOUIS SINCE 1899 HAS NOT BEEN DUE TO INFECTED WELLS OR MILK.

In his cross-examination Prof. Sedgwick, at page 2342, stated that as an expert in determining the source of typhoid infection, consideration should be given to all local conditions, and

reasonable search should be made for the purpose of determining the condition of wells out of which water might be used as well as the condition of the general water supplies. In this connection, speaking with reference to the condition of the wells in St. Louis, he stated there were about 3,000 wells in St. Louis and said, "I have considered the question of whether such a number was materially changed before and after. I have used my general knowledge of American communities and their behaviour in regard to wells and water supply. I have taken into account the typhoid fever and the characteristics of the population as nearly as I could ascertain them by inquiry and observation, and I have come to the conclusion that there is no reason to suppose that any material change in the habit of people in regard to the use of such wells or well water since the time mentioned has occurred, and that therefore that element may be entirely excluded as of consequence in causing any portion of the typhoid increase in St. Louis. I might even go further and say as between wells taken in a general way and including a certain number of polluted wells, and a city water supply not above suspicion, it is by no means clear to my mind that the use of such wells would increase the typhoid fever rate over and above the use of a water supply which is not entirely pure. I therefore exclude altogether the wells in St. Louis as producing an important part of the increase in typhoid fever since January 1st, 1900. I consider the information which I have received and which I now have upon the subject sufficient to establish my conclusion beyond all reasonable doubt."

The city of St. Louis is divided into seven sanitary districts, numbered one to seven, inclusive. In district number one there are four hundred and ninety-two wells; district number two, ten hundred and seventy-three wells; district number three, one hundred and one wells; district number four, ten hundred and fifty-eight wells; district number five, three hundred wells; district number six, three hundred and eleven wells; district number seven, eighteen hundred and seventy-seven wells.

The typhoid death rate for the respective years in the respective districts was as follows: District No. 1, 1900, 19 deaths;

1901, 19 deaths; 1902, 26 deaths; District No. 2, 1900, 14 deaths; 1901, 27 deaths; 1902, 21 deaths; District No. 3, 1900, 28 deaths; 1901, 30 deaths; 1902, 36 deaths; District No. 4, 1900, 24 deaths; 1901, 27 deaths; 1902, 34 deaths; District No. 5, 1900; 18 deaths; 1901, 18 deaths; 1902, 23 deaths; District No. 6, 1900, 42 deaths; 1901, 46 deaths; 1902, 57 deaths; District No. 7, 1900, 23 deaths; 1901, 30 deaths; 1902, 25 deaths.

It will be observed from the foregoing table that for the three years, 1900, 1901 and 1902, District No. 6, containing only 311 wells, had one hundred and forty-five deaths from typhoid fever, while District No. 7, containing 1877 wells, had 78 deaths from typhoid fever, and this comparison holds good throughout all the districts. (See Sedgwick's cross-examination, Vol. 3, pp. 2350, 2351.)

In this connection, Prof. Sedgwick stated: "There is absolutely no reason to suppose that a different condition prevails in the wells of the city of St. Louis since January 1st, 1900, than that which had prevailed there for years before, and I should regard it as absolutely impossible and absurd to attribute the excess of typhoid fever which has appeared in St. Louis since January 1st, 1900, to any such source. (See Sedgwick's testimony, Vol. 3, page 2356.)

In reference to typhoid fever from contaminated milk, Prof. Sedgwick made this statement:

"If the route of a dairyman covered the whole city, or any considerable part of it, it is possible that an infection might be spread from such source, but any epidemic produced in that fashion, of an appreciable size, is usually easy to discover, and there are none of the ear marks of an epidemic as far as I have been able to discover about the typhoid fever deaths in the city of St. Louis during the years 1900, 1901 and 1902. (See Sedgwick's cross-examination, Vol. 3, page 2352.)

25.

THE DOCTRINE OF SELF-PURIFICATION OF STREAMS DISCUSSED.

It is admitted by all the expert witnesses that so long as disease producing germs may live in water of running streams, the water may not be considered as having become purified from infectious material discharged into it from a point above, and the life of disease producing organisms depend largely upon the character of the flow and the amount of pollution and infectious material discharged into it. Dilution has a tendency to increase the longevity of organisms, and it is believed by some that oxidation and aeration also increases the opportunities for the life of pathogenic bacteria. Upon this subject Prof. Sedgwick, Vol. 3, page 2191, said, in answer to the question as to whether or not running water will purify itself so as to be free from pathogenic bacteria that may have been deposited in it, "In this whole matter of self-purification of streams we have today very different ideas from what we had twenty or thirty years ago. In trying to answer the question specifically and closely—if I try to answer specifically and closely—I shall have to say that running water under some conditions might very largely and possibly even altogether purify itself from infectious germs, but these conditions would have to be very unusual, and so unusual as to be practically theoretical, or virtually theoretical. It was formerly believed by experts that running water readily purifies itself. That belief has been abandoned. Acting upon that belief, which was the best state of our knowledge twenty or thirty years ago the numerous cities of the United States put in water works which should derive water from streams into which sewage was poured at points above. That was the best art of the time, and engineers, chemists and sanitarians agreed about it. In the city of Pittsburg, for example, which I have especially studied, the water supply was introduced from the Allegheny river with the confident belief that such sewage as might find its way into the river at points

above would be effectually removed before the citizens had access, in other words, before the water came to the citizens. That belief has been found to be erroneous. Pittsburg suffers today by typhoid fever perhaps more than any other city of the United States, certainly excessively. The cities on the lakes, Niagara Falls, Buffalo, Cleveland, Detroit, Chicago, Milwaukee and Duluth take water supplies subject or exposed to contamination by sewage, and are today considering the possibility of abandoning such supplies, owing to the failure of self-purification of sewage. Nevertheless there is a large measure of self-purification of streams. There is at times in certain streams, especially a large measure of self-purification. The subject is a complex and difficult one, and the tendency of opinion has been to increase our distrust in the efficacy of self-purification of water or sewage. Three or four years ago I examined this subject carefully, and arrived at the conclusion which I stated in a book published a year ago, before I had any expectation of connection with this case, which gave substantially the same point of view that I have stated, which I should be glad to read if it is proper. 'Today we realize that this theory of purification is only half true, and that such self-purification is only partial and absolutely unreliable. By a curious reversal of scientific opinion, we now hold that it is precisely running water which is least likely to purify itself, while stagnant or standing water, formerly looked upon with dread and suspicion, is now in much favor. The old theory was in vogue long enough to enable us to make a wonderful series of experiments, and on a stupenduous scale; experiments in which whole cities confidingly used for years, sewage polluted water, often with sad results, but results of lasting instruction to mankind. Never again so long as civilization endures, will intelligent communities, acting under expert advice, repeat these sad experiments.' " (Sedgwick's testimony, Vol. 3, page 2193.)

Further on, Prof. Sedgwick said:

"I have given some attention to typhoid fever in Chicago, and I have also given attention to the condition of affairs at Detroit, Cleveland, Buffalo and Niagara Falls, and I found in

Buffalo, rather to my surprise, a prevailing feeling among medical men that the time was at hand when Buffalo has got to purify her water because of the pollutions put into the lake at Cleveland and higher points. I found that at Niagara Falls they were suffering severely from typhoid fever, which the physicians there, who were present at my lecture, freely expressed themselves as believing to be derived from the sewage of Buffalo, which had run down the Niagara river. I think it is a great question whether the big lakes, or rather the people who are using the big lakes, have not got to give up the use of them after awhile. A while ago Prof. Jordan reported practically to that effect for Chicago, and Detroit certainly stands in great danger from pollutions at Port Huron and possibly other points, and Cleveland, I have been told, though I am not sure of this, is seriously thinking of giving up its tunnels and going into filtration because the water that comes down from above is polluted, and the whole question of the extent of pollution of water supplies and the life of the typhoid germs—typhoid and other disease germs in water, is today a very seriously debated question, and as I said this morning, the growth of opinion is more and more towards the idea that it will not do to trust to self-purification provided you have got upon your watershed a very heavy or extensive pollution."

"I may say right here, and in this connection we might as well be done with this once for all. We used to think that running water, when it got thoroughly aerated, purified itself, especially if it came from long distances. That was the theory on which Pittsburg put in its water works. That was the theory upon which Lowell took the obviously sewage polluted water of the Merrimac and used it for water supply purposes. It was one of the commonest things that chemists and sanitarians believed, and they had reason to believe at that time, that running water from even moderate distances would so purify itself as to be safe; but Pittsburg, Lowell and Lawrence, and so far as I know, nearly all of the cities that have trusted to that, have been typhoid ridden, and today, as I reported at Pittsburg, the distance of 100 miles, or even more remote points, infection coming from Oil City, 113 miles, or even more remote points,

may produce typhoid fever. It is not today so much a question of distance; it is the question of giving time for the germs to settle out and to die out, and it is dilution and time of quiescence, particularly quiescence. It is simply a question of time. You have got to eliminate all idea of distance from these things, and bring in the question of time largely, and that it was I stated in my treatise on Sanitary Science and Public Health written two or three years ago. It is nothing that I have gotten up for this case, or anything of that kind. It is a fact that is borne in upon me by long experience, and I believe that in that respect I stand entirely square with the sanitarians of the world.

"The amount of infectious pollution does not affect the time needed but the degree of danger. The amount of infectious pollution affects the degree of danger; it would not affect the time, that is the time for each individual microbe. Of course, that is its own individual problem. One microbe coming down from Chicago and resting quietly in the slack water of the Illinois, if it lay there long enough would probably die out, I would say must certainly die out if it lay there long enough. Of course, some one might not agree with me on that, but I think so. But, of course, if a million came down the chances that some might be carried on by a little freshet, or something of that kind before they had died out, would be greatly enhanced and other things being equal, the larger the infection the more serious the danger.

(Sedgwick's evidence, Vol. 3, pp. 2211, 2212.)

FACILITIES FOR SELF-PURIFICATION IN THE ILLINOIS RIVER WERE BETTER UNDER THE CONDITIONS EXISTING PRIOR TO OPENING OF THE CANAL THAN UNDER THE CONDITIONS WHICH HAVE EXISTED SINCE THE OPENING.

Prior to the opening of the Drainage Canal, the Illinois river was a slow, sluggish stream, and during the greater part of the year there was practically no current in it. A chunk, or block, thrown in the water above any of the dams of which there are five, would remain quiet unless carried one way or the other

by the force of the wind. During a great part of the year the water was covered with a green scum, showing that putrefaction and self-purification was in process. Since the drainage canal has been opened there has been a constant, continuous and strong current of water passing from the source of the river to its mouth. Its facility for septic operation has been destroyed. Based upon modern discoveries, the quiescent state is conducive to self-purification of water, and that a moving body of water has the tendency to prolong the life of pathogenic bacteria contained in it. Less bacteria are now perishing in the waters of the Illinois river than prior to the opening of the canal, even though it be considered that large quantities were deposited therein during both periods.

(Sedgwick's testimony, Vol. 3, page 2193.)

The increase made in the speed of the current of the river by the addition of the water of the Drainage Canal, which necessarily increases the current, has the effect of increasing the liability of typhoid and pathogenic bacteria passing down the river to reach the Mississippi, and consequently has had the tendency to increase typhoid fever among the people using water for domestic purposes.

(Sedgwick's testimony, Vol. 3, page 2196.)

Before the canal was opened the facilities for sedimentation were exceedingly great in the Illinois river, and since that time, by the increase in rate of flow, pathogenic bacteria are carried in large quantities directly through the canal, through the Des Plaines and Illinois rivers to the Mississippi.

(Sedgwick's testimony, Vol. 3, pp. 2197, 2219, 2220, 2221; Whipple's testimony, Vol. 3, pp. 2085, 2086, 2087, 2088; Keiser's testimony, Vol. 2, pp. 1045 to 1049.)

26.

THE DANGER TO THE PEOPLE OF ST. LOUIS AND MISSOURI CAUSED BY THE OPENING AND OPERATION OF THE CHICAGO DRAINAGE CANAL IS ACTUAL, CONSTANT, IMMEDIATE AND CONTINUOUS.

The chemical and bacterial analyses of the water in the Illinois and Mississippi rivers show that the opening of the drainage canal and its operation since January 17, 1900, has at all times rendered the waters of the Mississippi river at the Intake of the St. Louis water supply unsuitable for domestic use, while prior to that time it is shown to have been a reasonably safe water. By the addition of a population of over two millions of people to the watershed of the Mississippi river, and subjecting the Mississippi river to additional polluted water from the canal and the sewage of the added population, it is evident that the velocity or stream flow of from ten to fifteen days required for the water to pass from Chicago to St. Louis, not only renders the water unsuitable for domestic purposes, but constitutes a constant, immediate and continuous danger to the people of St. Louis and of the State of Missouri using the water of the Mississippi river below Grafton for domestic purposes. In this connection Prof. Sedgwick stated as follows:

"I believe that the danger is practically constant, by which I mean that it can never be known at what moment infectious material may arrive from the sewers of Chicago. I do not suppose that such material is arriving every minute, or every hour, but I believe that the danger is constant, because we never can know when it may come. I believe it is immediate, in the sense that it is urgent and serious; and I believe that it is impending; from the fact that it is, as it were, hanging over the citizens of Missouri on the shores of the Mississippi all the time. I cannot help looking at the thing in this way. It is as if there were now located on the watershed of the Mississippi, since the opening of the drainage canal, a large additional city, a city notorious for its typhoid death rate, or for its typhoid

epidemics, I would say, and for its high death rate, too, from typhoid fever; and as if the placing of that city virtually upon the Mississippi watershed had introduced a new element into the life and welfare of the people on the river below. It is no trifling matter to take on a city of that size and add its sewage to an already sewage-polluted stream. The danger line may, by that addition, be reached soon—must, in the nature of things, be reached sooner—by those who use the water, and it is for that reason that I do regard the danger as impending, immediate and aggravated, as well as continuous."

(Sedgwick's testimony, Vol. 3, pp. 2217-18, 2225.)

Mr. Williams, at page 2467, stated in this connection as follows:

"In the history of water-borne diseases in America, while typhoid fever plays an important part, it comes far short of playing the entire part. Not only Asiatic cholera, but a large number of our common American diseases are undoubtedly transmitted through the water. Among those germs which have been found to have a considerable length of existence in water are the germs of diphtheria, tetanus, and anthrax, as well as a considerable number of germs which are derived from the diseases of the lower animals. The germ of anthrax, for instance, is capable of producing very serious disease in both man and beast, and there have already occurred in the city of St. Louis cases of anthrax, one of which has been traced, apparently, to the water supply, and the germ of anthrax is reported to have been found in the waters of the Illinois river. Anthrax is primarily a disease of the lower animals, and in France, where it has been especially prevalent in some provinces, it has been no uncommon thing for ten per cent of the sheep to be destroyed by it in a single year. A peculiarity of anthrax is the remarkable length of life of its spores, or seeds—which ever you may choose to call them—in water, they have been known to exist in it not only for months, but for years, and are practically indestructible. Should anthrax be prevalent among cattle, which are daily slaughtered in the Chicago stock yards, and from them be transmitted by the discharges from the nostrils, mouths or

bowels of those cattle into the sewers of Chicago, there would be no question that the germs of anthrax might easily find a lodging in the people of Missouri with extremely fatal results. The germ of anthrax may not only be taken into the human system and produce disease by passing into the intestinal tract, but it is also susceptible of producing disease as a result of innoculation, so that a person bathing in water in which there were present germs of anthrax, if he had on his body any abrasions of the skin, would be particularly liable to receive an infection from anthrax, which might very probably end fatally. The germ of anthrax being practically indestructible under ordinary conditions, is frequently conveyed in hides and skins, and in the refuse from leather manufacturing establishments might easily get into the sewage of the city of Chicago as well as by way of the stock yards.

"The people of the State of Missouri, resident in the counties bordering upon the Mississippi river are largely engaged in stock raising, and in times of drought, the Mississippi river is practically the only source of water for the stock so raised, and it has come to my knowledge that in such times this water is carted for many miles from the shores of the Mississippi river to be used by both stock and the human inhabitants of the country adjacent. Should the sewage of Chicago become infected with germs of anthrax, and should those germs be transmitted, as they undoubtedly would be, into the waters of the Mississippi, if the Chicago Drainage Canal continues to discharge the sewage of Chicago into the Des Plaines and Illinois rivers, at such times there would be great danger of the occurrence of an epidemic of anthrax, not only among the human inhabitants of the State of Missouri, but also among the lower animals using the water. Anthrax is recognized as one of the worst of water-borne diseases with which we have to contend, for the reason that when once it becomes established in a community it may attack both man and beast, and its eradication can only be accomplished by the absolute destruction of the bodies of animals so infected. I may further add that the disease commonly known as glanders is also transmitted through water, and that it is not an uncommon disease among the stock of this country

at the present time, and the discharge of the sewage of Chicago, which is at any time liable to be contaminated by glanders, into the Illinois river, is another source of danger to the inhabitants of Missouri. In fact, as we look into the future and see the probable growth of Chicago, both in industries and in population, and the added probability of infection of its sewage due to the more general spread of infectious diseases, it seems to me that the danger impending over the citizens of Missouri as a result of the discharge of the sewage of Chicago through the drainage canal into the waters of the Illinois river is a most fearful menace to the health and welfare, not only of the citizens of Missouri, but of the citizens of other cities below the mouth of the Illinois river, leaving entirely out of consideration the question of typhoid fever."

From all the facts presented in the case, taking into consideration the extent of typhoid fever deaths on the Illinois, Missouri and Mississippi river watersheds, exclusive of the city of Chicago, during the last four years, and comparing the same with the number of deaths occurring on the same watersheds, exclusive of Chicago, from 1895 to 1900, it is apparent that the opening of the Drainage Canal has been and is now a constant menace to the people of St. Louis and the State of Missouri using the water of the Mississippi for drinking purposes.

(Sedgwick's testimony, Vol. [illegible] pp. 2201-2230-2231.)

27.

THE EFFECT OF THE SEWAGE OF CHICAGO UPON THE WATERS OF THE MISSISSIPPI AT THE CHAIN OF ROCKS IS SUCH AS TO PRODUCE AN INCREASE IN THE COST OF THE CONSTRUCTION AND OPERATION OF A SUITABLE FILTRATION PLANT TO PROTECT THE PEOPLE OF THE CITY OF ST. LOUIS AGAINST INFECTIOUS MATTER COMING FROM THE ABOVE NAMED CITY.

The constantly increasing amount of bacilli from the Sanitary District of Chicago, infected with disease producing organisms, coming through the Chicago Drainage Canal into the Mississippi river, will not render the water much less safe, generally speaking, than it was prior to the opening of the canal, but, by increasing the amount of infection and infectious material it creates an added responsibility as regards the treatment of the water of St. Louis so as to make it perfectly safe and wholesome for the people and citizens for consumption. Such treatment of the water under the conditions that exist now would involve a greater responsibility and financial expense. This increase in the cost would be shown by greater expense of supervising of the plant, and added cost of supplies used in connection with the operation of the works. It would also mean that such works be operated from time to time at lower rates of filtration than if the increase in infection were not present. The significance of this, that by reducing the rate of filtration, a larger plant will be required, and hence the more expensive an installation for the works to purify the same quantity of water than in the instance of water without the added infectious matter.

Looking into the future, and considering the various centers of population naturally tributary to the Mississippi river at St. Louis, the Missouri and Illinois rivers, excluding the Chicago Sanitary District, it is certain that there will ultimately

come a time when double filtration will be required to produce the results that single filtration can hardly be expected to produce now. When that time will come it is, of course, difficult to state specifically, as that will depend upon the rate of growth of the population of the cities situated upon the Illinois, Mississippi and Missouri rivers. But whatever the rate of growth may be, it is certain that the added infection will hasten the day when single filtration at St. Louis will prove unsatisfactory, and when it will be necessary to install a system of double filtration, which will necessarily involve an increased expense.

(Fuller's testimony, Vol. 3, pp. 2623-24.)

It is possible that the Illinois river might, under present conditions, become a stench to the nostrils of the people, in which case quadruple filtration is a possibility. And quadruple filtration may be necessary if the city of St. Louis persists in taking this water from the river. It is also possible that other types of purification may be required in connection with filtration, and the Chicago sewage will certainly very much hasten that day, whenever it may come.

(Fuller's testimony, Vol. 3, p. 2628.)

When water is being filtered for any purpose it ought to be done in the best possible way, having regard to the health of the people who drink it.

(See Fuller's testimony Vol. 3, pp. 2632-37, inc.; Williams' testimony, Vol. 3, pp. 2402-3; Sedgwick's testimony, Vol. 3, p. 2382; Dr. Herbert E. Smith's testimony, Vol. 8, p. 7723.)

On this subject Dr. H. E. Smith testified thus:

"Q. Doctor, taking into consideration all the analytical data introduced in evidence by defendants and found in Streams Examination or otherwise, and taking into consideration the fact that Chicago sewage is discharged into the Illinois river by means of the Drainage Canal, and that the Sanitary District of Chicago has a population of more than 1,700,000, which is constantly and rapidly increasing, and taking into considera-

tion the bacterial and chemical results shown from the analysis introduced in evidence, taking into consideration the physical surroundings and conditions existing upon the Illinois river and the Mississippi river watershed above the Chain of Rocks, at all times and all seasons of the year, I will ask you to state whether or not, if a filtration plant should be established at St. Louis, the cost of its operation would be increased on account of the opening of the Drainage Canal and the passage of the sewage through the canal into the Illinois river, and taking into consideration the fact of this large amount of sewage continuously being discharged from the city of Chicago, state whether or not the operation of such a plant would require less cost if the deleterious and dangerous and infectious substances contained in the waters discharged from the canal into the river were eliminated from that river?"

"A. Taking into consideration the facts which you have called to my attention, I would state it as my opinion that the installation and operation of a filter plant at St. Louis would be more expensive by reason of the discharge of the sewage from Chicago into the Illinois river, and that if the deleterious agents in this sewage were removed that the cost of the installation and the maintenance of a filter plant at St. Louis would be lessened."

(Dr. H. E. Smith's testimony, Vol. 8, p. 7723.)

John W. Alvord testified thus:

"Q. Taking into consideration your knowledge of septic operation, and all that you know upon the subject of sanitary science and sanitary hydraulic engineering, and taking into consideration the physical condition of the Illinois river, the Drainage Canal and the Des Plaines river, and the chart or diagram introduced in evidence by Mr. Herring, and the diagram introduced in evidence by you in connection therewith, state whether or not in your opinion the presence of sewage from the Sanitary District of Chicago in the waters of the Mississippi river at the Chain of Rocks makes it more costly to provide suitable water for domestic purposes for the citizens of St. Louis?

"A. In my opinion it does make it more costly.

"Q. In what respects is the water supply of St. Louis made more costly or difficult by virtue of the opening of the drainage canal?

"A. The design and construction of a purification plant dealing with a seriously polluted water, especially of one of known high typhoid pollution should be more complete and delicately adjusted to its work than when dealing only with water of rare infection and presenting less dangerous difficulties such as turbidity and color.

"Q. What form should this added protection take?

"A. It should take the form either of double filtration or have complete sedimentation in more than one stage followed by most careful filtration.

"Q. State whether or not you know of any case where double filtration is being used or resorted to?

"A. It has been resorted to in several places in Germany, and has been recommended at Springfield, Massachusetts, by Messrs. George W. Fuller and Samuel M. Gray, and is now being introduced into the new filtration plant of Philadelphia by Mr. John W. Hill, in which case they are proposing to pass water of known typhoid pollution through what are called preliminary filters as a first stage, and then through slow sand filters as a second stage.

"Q. Would such methods be more expensive than single filtration?

"A. They would. It is my opinion that they would very greatly increase the cost of filtration, both in its first construction and in operation.

"Q. State whether or not single sand filtration as practiced in the United States is always a protection from the danger of typhoid infection?

"A. It is not.

"Q. Why is it not?

"A. Sand filtration of either type is practically able to remove pathogenic bacteria from domestic water supply, but we find that in practice filtration works are a most delicate mechanism, which have to be very carefully operated in order to produce at all times and under all conditions the results

anticipated by their designers. In cases where the danger of infection hovers over the filtration plant year in and year out it is obvious that the slightest relaxation may result in the most serious consequences.

"Q. State whether or not you know from your own observations and study of the cases in which single sand filtration or filter plants of either type have failed to protect the water supplies from typhoid infection?

"A. I do. There have come under my observation, typhoid epidemics in water supplies protected by filtration in the following places:

Rock Island, Illinois.
Ashland, Wisconsin.
Berlin, Germany.
Lawrence, Massachusetts.
Lake Forest, Illinois.
Butler, Pennsylvania.
Waterloo, Iowa.
Beaver Falls, Pennsylvania, and
Augusta, Maine.

"Q. Mr. Alvord, are you a member of any engineering societies or associations?

"A. Yes, sir; I am a member of the American Association of Civil Engineers since 1893. I am a member and trustee of the Western Society of Civil Engineers. I am president of the Illinois Society of Civil Engineers and Surveyors. I am a member of the American Waterworks Association, and of the New England Waterworks Association. I am also a member of the American Public Health Association, and am serving this year upon its committee of water and sewage purification. I am a member of the American Association of Municipal Improvements of the American Academy of Social and Political Science, and of the Engineers' Club of Chicago."

(Alvord's testimony, Vol. 8, pp. 7791-2.)

28.

COMPARISON OF TYPHOID FEVER DEATHS IN ST. LOUIS BEFORE AND AFTER THE OPENING OF THE CHICAGO DRAINAGE CANAL WITH OTHER CITIES.

In making a comparison of the typhoid deaths with like deaths in various cities of Europe and in the United States, Dr. Ravold testified as follows:

"The tables were taken from Hill's Work on Public Water Supply, and the number of deaths recorded are for each hundred thousand population.

ROTTERDAM.

"The water supply of this city is filtered, the water being taken from the Rivers Rhine and Maas. The number of deaths per hundred thousand population is as follows:

1890 6 deaths per hundred thousand population.
1891 4 deaths per hundred thousand population.
1892 6 deaths per hundred thousand population.
1893 5 deaths per hundred thousand population.
1894 5 deaths per hundred thousand population.
1895 2 deaths per hundred thousand population.
1896 12 deaths per hundred thousand population.

MUNICH, BAVARIA.

"Munich obtains its water supply from springs in the mountains, brought from Mangfall Valley, about 38 miles away.

1890 8 deaths per hundred thousand population.
1891 7 deaths per hundred thousand population.
1892 3 deaths per hundred thousand population.
1893 15 deaths per hundred thousand population.
1894 2 deaths per hundred thousand population.
1895 3 deaths per hundred thousand population.
1896 3 deaths per hundred thousand population.

BERLIN, GERMANY.

1890 9 deaths per hundred thousand population.
1891 10 deaths per hundred thousand population.
1892 8 deaths per hundred thousand population.
1893 9 deaths per hundred thousand population.
1894 4 deaths per hundred thousand population.
1895 5 deaths per hundred thousand population.
1896 5 deaths per hundred thousand population.

VIENNA.

"Vienna takes its water supply from springs in the Schneeberg mountains.

1890 9 deaths per hundred thousand population.
1891 6 deaths per hundred thousand population.
1892 8 deaths per hundred thousand population.
1893 7 deaths per hundred thousand population.
1894 5 deaths per hundred thousand population.
1895 6 deaths per hundred thousand population.
1896 5 deaths per hundred thousand population.

CHICAGO.

"Unfiltered Lake Michigan water.

1890 92 deaths per hundred thousand population.
1891 154 deaths per hundred thousand population.
1892 106 deaths per hundred thousand population.
1893 45 deaths per hundred thousand population.
1894 31 deaths per hundred thousand population.
1895 32 deaths per hundred thousand population.
1896 46 deaths per hundred thousand population.

PITTSBURG.

"Unfiltered river water.

1891 100 deaths per hundred thousand population.
1892 100 deaths per hundred thousand population.

1893 111 deaths per hundred thousand population.
1894 56 deaths per hundred thousand population.
1895 77 deaths per hundred thousand population.
1896 61 deaths per hundred thousand population.

LOUISVILLE.

"Unfiltered Ohio river water.
1890 88 deaths per hundred thousand population.
1891 81 deaths per hundred thousand population.
1892 72 deaths per hundred thousand population.
1893 84 deaths per hundred thousand population.
1894 72 deaths per hundred thousand population.
1895 77 deaths per hundred thousand population.
1896 45 deaths per hundred thousand population.

ST. LOUIS.

"Unfiltered Mississippi river water.
1890 94 deaths per hundred thousand population.
1891 30 deaths per hundred thousand population.
1892 37 deaths per hundred thousand population.
1893 103 deaths per hundred thousand population.
1894 31 deaths per hundred thousand population.
1895 19 deaths per hundred thousand population.
(Dr. Ravold's testimony, printed record, Volume 1, pp. 753-754-755.)

1896-1899, inclusive, 19.6 deaths per hundred thousand population.

1900-1903, inclusive, 34.7 deaths per hundred thousand population.

29.

THE ACTUAL INJURY AND PERMANENT DAMAGE TO COMPLAINANT BY DEFENDANTS.

The full injury to complainant is apparent, beyond all doubt, as shown by the testimony in chief of Mr. Geo. W. Fuller and the rebuttal testimony of Mr. John W. Alvord, Dr. Herbert E. Smith and Prof. W. T. Sedgwick. Every word of it goes to the merits of the case with marked continuity and cannot well be disjointed. We therefore set forth portions of it in full:

MR. FULLER, testified in part as follows:

Q. Mr. Fuller, I will get you to state as a sanitary and water supply expert, what you consider to be the best index to the sanitary character of a public water supply?

A. As a general proposition it is my judgment that the best index to the sanitary character of a public water supply is the mortality record from water-borne diseases in the community using the water supply in question, and especially the mortality statistics of typhoid fever.

Q. Mr. Fuller, I will get you to state why the mortality satistics of typhoid fever are a better index, in your judgment, to the character of a water supply in a community than those of other water-borne diseases?

A. It is my experience that the typhoid fever mortality statistics are preferable to those of other water-borne diseases for a number of reasons, of which the principal ones are the wide-spread nature and distribution of typhoid fever, its abundance in those communities having supplied to them sewage polluted water; the well defined character of the disease, taking everything into consideration, and also the substantially large percentage of deaths to those who have the cases, that is, the percentage of deaths to cases is larger than in some other instances. If Asiatic cholera should become established in this country I dare say that that might serve as an index to the sanitary character of water, substantially as well.

Q. Mr. Fuller, do you know how many people generally speaking, sicken and die of typhoid fever each year in the United States?

A. Some years ago I gave that matter careful consideration. Generally speaking I would place the number of typhoid deaths on a very conservative basis, as at from 25 to 30 thousand annually in this country. As to the number of cases occurring in this country annually, of typhoid fever, I would place the figure at more than a quarter of a million.

Q. Mr. Fuller, what in your judgment was the sanitary character of the municipal water supply of St. Louis, after having passed through the settling basins as delivered to the consumers, during the years 1895 to 1899, inclusive, and upon what do you base your conclusions?

A. It is my judgment that the water supplied to the citizens of St. Louis by the municipal water department during the years 1895 to 1899, inclusive, was what might be called a good sanitary water. I base that judgment upon this fact: during the period mentioned, the typhoid fever mortality statistics showed as low a rate approximately speaking, as in the case of quite a number of other American cities having a pure or very nearly pure water supply.

Q. Mr. Fuller, what treatment was given to the raw river water after its entrance into the itnake tower at the chain of rocks and before its entrance into the service pipes of the consumers, in the city of St. Louis during the period from 1895 to 1899, inclusive, and how if at all, did that treatment affect the sanitary character of the water?

A. The treatment at that time, that is from 1895 to 1899 inclusive, consisted of settling the water in the basins at the chain of rocks, which process I have already outlined in its general features. The result of this settling was to improve the water to a considerable degree as regards the elimination both of mud and of bacteria, including those of a pathogenic nature when such were present in the raw river water.

I will add another thing, and say that there was substantially no change in the period for sedimentation during the years in question.

Q. I will get you to state Mr. Fuller, whether or not the term "pathogenic bacteria" is used by you to include water-borne bacteria that might convey infectious diseases such as cholera and typhoid?

A. Yes, sir.

Q. Mr. Fuller, what in your judgment, was the sanitary character of the raw Mississippi river water as it entered the chain of rocks intake tower, St. Louis waterworks, during the years 1895 to 1899, inclusive?

A. It is my judgment that the raw Mississippi river water entering the intake tower during the period 1895 to 1899, inclusive, was a much less safe water from a sanitary standpoint than was the water after it had been treated in the settling basins, and delivered to the consumers. This was due of course to the elimination of bacteria of an injurious nature, by the process of sedimentation, and in which process the injurious bacteria subside—fall to the bottom of the basin and from time to time are removed from the basin and thus prevented from passing on with the water delivered to the consumers.

Q. How are the deposits made in the settling basins of the St. Louis waterworks removed, by the action of the water or by artificial means?

A. They are removed by artificial means, that is to say, once or more each year, the basins are emptied, and the mud is flushed by the aid of water, into channels, which conduct the mud to a sewer leading from the end of the basins to the river, and down below, a considerable distance below the intake tower.

Q. Mr. Fuller, referring to the sanitary character of the raw river water as it entered the chain of rocks intake tower during the years 1895 to 1899, inclusive, how would you classify that water as a city water supply?

A. I would classify it in its sanitary character, as a suspicious water, meaning by that not distinctly a good water, but one in which there was a liability of danger from time to time to those who drink it in its raw condition.

Q. Mr. Fuller, I will get you to state if you know how the typhoid fever statistics in the city of St. Louis for the period

since January, 1900, compare with those of the five preceding years, and if so, state the comparison?

A. During the period from 1895 to the end of the year 1902, the number of deaths from typhoid fever each year was as follows:

1895	106,
1896	107,
1897	125,
1898	95,
1899	130,
1900	168,
1901	197,
1902	222.

Averaging the number of deaths from typhoid fever during the five years, 1895 to 1899, inclusive, gives 112 deaths per annum from typhoid fever. The average annual deaths from typhoid fever during the three years beginning with January, 1900, is 196, showing an increase in round numbers in the number of deaths, of about 80 per cent.

Taking into consideration the differences in population, that is, the increase in population during that period, and expressing the typhoid fever deaths with reference to the number per 100,000 of population living, there has been an increase during the past three years on an average of about 60 per cent over the annual typhoid fever death rate per 100,000 population living, for the five years 1895 to 1899, inclusive.

Comparing the number of deaths from typhoid fever during these eight years, with reference to the total number of deaths from all causes, occurring in the city of St. Louis, and obtaining the percentage mortality from typhoid fever, the percentage increase for the last three years on an average as compared with the average percentage of mortality from typhoid fever during the five preceding years, is 73 per cent.

I will further state that the average number of deaths from typhoid fever in St. Louis during the first five years under consideration was about 20.4 per 1,000,000 population living, and that this rate during the past three years, on an average, was

about 32.3 on the same basis; that is, the average number of deaths per annum per 100,000 population living.

Q. Mr. Fuller, I will get you to state if in your judgment the three methods of investigating and comparing typhoid fever statistics afford, when considered together, a proper and reasonable basis upon which to base conclusions with reference to typhoid fever statistics of the city?

A. In my judgment that is true, for the reason that each throws light upon the matter, but the data regarding the two last methods of comparison taken together, are the fairest and best way.

Q. Now, Mr. Fuller, I will get you to state, speaking broadly, what in round numbers, considering all of these methods, and all of the facts, you consider the increase of typhoid in St. Louis to be, in the periods mentioned in the former question?

A. I should say in round numbers there has been an increase during the second period under consideration of about sixty to seventy per cent above the average rate in the earlier period mentioned.

Q. Mr. Fuller, I will ask you if you know how the typhoid fever statistics of the city of St. Louis for the period covered by the first five months of each year since 1895 to 1899, inclusive, compare with the first five months of the three years since January, 1900, if so, state what that comparison is?

A. The number of deaths from typhoid fever in St. Louis during the first five months of the years 1895 to 1899, show sums or amounts very much less than during the first five months of each of the years following 1899; that is, 1900, 1901, 1902 and 1903. This is particularly true of the present year, 1903.

Q. Do you know, Mr. Fuller, the mortality from typhoid fever for the five months of the year 1903 by months?

A. In January, 1903, there were 15 deaths.
In February, 1903, 15 deaths.
In March, 20 deaths.
In April, 17 deaths, and
In May up to date, 18 deaths.

Q. These statistics are for the city of St. Louis are they, Mr. Fuller?

A. City of St. Louis.

Q. Mr. Fuller, are you enabled by any methods of judgment of typhoid statistics, that you have mentioned, and from your general knowledge to say whether or not these figures for the year 1903 indicate an increase or a decrease of the typhoid fever in this city?

A. They clearly indicate an increase in typhoid fever in this city.

Q. Mr. Fuller, I will get you to state if you know whether or not from the facts in your possession and the statistics that you have stated and are aware of, if typhoid fever shows any signs of abating in this city?

A. The record of the number of deaths from typhoid fever in the city of St. Louis by months, shows a continuance of these comparatively high figures to an unusual degree, showing that for this season of the year there is an unusual prevalence of this disease in this city.

Q. Mr. Fuller, I will get you to state to what cause you ascribe the increased mortality from typhoid fever in the city of St. Louis since January, 1900, and why?

A. I ascribe it to an increased amount of infection in the public water supply, and predicate this opinion upon the practically uniform distribution of the homes or residences in which the typhoid deaths have occurred in the city of St. Louis, and the further fact that a careful examination of the several other possible sources of typhoid fever shows that no substantial portion of this increase may be explained in that way.

Q. Mr. Fuller, what in your judgment has been the sanitary character of the public water supply of St. Louis after passing through the settling basins as delivered to the water consumers since January, 1900?

A. I consider that the sanitary character of the public water supply delivered to the consumers in the city of St. Louis has been less safe than it was formerly.

Q. Mr. Fuller, I will get you to state if, in your judgment, the water supply of St. Louis, as delivered to the consumers,

after passing through the settling basins since January, 1900, can any longer be classed as a good water?

A. It is my judgment that it cannot be classed as a good water.

Q. Mr. Fuller, what has been the treatment of the raw river water after it leaves the chain of rocks, intake tower, and prior to its reaching the consumers in the city of St. Louis during the period since January, 1900, as compared with the five preceding years?

A. The treatment has been essentially the same.

Q. Mr. Fuller, what in your judgment, has been the sanitary character of the raw Mississippi river water as it enters the chain of rocks intake tower, since January, 1900, and how does it compare with that of the five preceding years?

A. I consider that the sanitary character of the raw Mississippi river water entering the intake tower of the St. Louis waterworks since January, 1900, has been distinctly and decidedly less safe than during the five preceding years.

Q. Mr. Fuller, generally speaking, what is the principal source of dangerous impurities in public water supplies in their raw condition?

A. Sewage pollution.

Q. Mr. Fuller, I will ask you if you are familiar with the relative amounts of typhoid fever prevailing on the area naturally tributary to the Mississippi river above the chain of rocks, for the five years preceding, and the three years since January, 1900, and what do you say as to the relation between the conditions in the sanitary character of the raw Mississippi river water at the chain of rocks intake tower and the prevalence of typhoid fever within the natural limits of the Mississippi watershed above St. Louis; that is, exclusive of the Chicago Sanitary District?

A. I am generally familiar with the typhoid fever statistics in the larger centers of population upon the Mississippi watershed, above the chain of rocks, intake tower of the St. Louis waterworks, and excluding the Chicago sanitary district during the periods mentioned in the question. During these periods there have been at quite a number of points some variation

in the amount of typhoid fever prevailing in different years. Taking the typhoid fever statistics upon this watershed area as stated, as a whole, but excluding the Sanitary District of Chicago, based upon the average number of deaths from typhoid fever per year, it is my judgment, viewing the matter as a general proposition, that there has not occurred on the natural area of the Mississippi watershed above St. Louis any increase in the number of deaths sufficient to explain to any material degree the less safe condition of the Mississippi river water as taken from the intake tower of the St. Louis waterworks, during the last period, as compared with the period of 1895 to 1899.

Q. I will get you to state, Mr. Fuller, if you know of any cause that renders the water, if it is, less safe—that renders it so at the intake, at the chain of rocks now, and within the last three years, than prior to January, 1900?

A. In my judgment, it is the Chicago Drainage Canal discharging sewage and drainage containing filth and infection, from the city of Chicago, which makes the water in its raw condition at the intake tower, chain of rocks, St. Louis waterworks, less safe than it was preceding January, 1900.

Q. Mr. Fuller, I will get you to state if you know how many deaths from typhoid fever have occurred since January, 1900, in the city of Chicago, and what has been the disposition of the infectious discharges of the persons sick with this disease?

A. There have been about 1647 deaths from typhoid fever in Chicago since January, 1900, and the infectious discharges from the persons sick and dying of typhoid fever have to a very large degree been disposed of by their passage through the sewers to the Chicago river and the Chicago drainage canal.

Q. Mr. Fuller, I will get you to state whether or not you have made an estimate of the approximate number of persons sewering into the Mississippi river and its tributaries, exclusive of the Sanitary District of Chicago. If so, what figures have you obtained and upon what basis as to the separating of the rural from the sewage contributing population?

A. I have looked into this matter and in round numbers place the figure for those people who sewer directly into the Mississippi and its branches and tributaries above the St. Louis

waterworks and exclusive of the Sanitary District, at about 2,700,000. This figure is based upon a separation, on an average of the sewage contributing population from the rural population by taking towns of 4,000 and over as representing those who have sewerage systems and contribute sewage directly to the water courses. Some of the towns of more than 4,000 population are undoubtedly not provided fully with sewerage facilities. On the other hand, there are quite a number of towns of less than 4,000 population which in a limited measure do have waterworks, and do have some sewerage. Looking at this question as a practical proposition, it is my judgment that the amount of the sewage-contributing population in towns of less than 4,000 inhabitants no more than off-sets in the aggregate the amount of population in the cities larger than 4,000 inhabitants which do not have sewers. It is a fact well known among practical waterworks and sewerage people that the number of miles of water mains in a town ordinarily exceeds to a considerable degree the number of miles of sewer lines. In making this statement as to the number of people in the aggregate sewering into the Mississippi river above the chain of rocks intake, I include of course, the Missouri river and the Illinois river, exclusive of the Chicago Sanitary District, as well as the upper Mississippi.

Q. Mr. Fuller, why did you draw a line at the towns of 4,000 inhabitants for the separation of population contributing pollution directly, from those which contribute indirectly?

A. Well, that matter I took up pretty thoroughly in the last answer I gave, and will state that the basis as described in my last answer is the result of my experience and I think that no the whole it is a reasonable and fair method due to its compensation of the two factors; first, the amount of population in the cities above 4,000 which do not sewer directly into the river and secondly, the population of some towns of less than 4,000, which do contribute sewage directly to the water courses.

Q. Mr. Fuller, what would you estimate to be the percentage of increase in population sewering into the Mississippi river valley above St. Louis, due to the Chicago Drainage Canal bringing sewage of Chicago into the Mississippi river watershed?

A. In round numbers I estimate an increase of 60 per cent.

Q. Mr. Fuller, please state, if you know, what course the diluted sewage follows, after the contents of the drainage canal, containing the filth and infection of the Chicago Sanitary district, after it flows from the Bear Trap Dam at Lockport and into the Des Plaines river?

A. The contents of the Chicago drainage canal after entering the Des Plaines river below the Bear Trap Dam at Lockport, flows along the course of the Des Plaines river, which river joins the Kankakee, and the two form the Illinois river. The contents of the drainage canal thence flow throughout the entire length of the Illinois river and enter the Mississippi at Grafton, which is distant about 291 miles from Lockport.

Q. Mr. Fuller, how long a time do you estimate is required for the Chicago sewage to flow this distance of 291 miles from Lockport to Grafton?

A. I place the figures ordinarily at from ten to twenty-five days. That range of course depends on the velocity of flow of water in the river.

Q. What would you estimate the average to be in time to make the flow from Lockport to Grafton?

A. It is my opinion that the average time required for the flow from Lockport to Grafton is about 15 to 18 days. In this connection I would further state that there are portions of the stream, mainly the upper portions, which flow more rapidly than the lower portions, and some water presumably reaches Grafton quicker than indicated by the average above mentioned.

Q. Mr. Fuller, what, in your judgment, is the period of time which typhoid fever germs may and do continue to live in sewage polluted waters such as are found in streams, reservoirs and the like?

A. I consider that they may and do continue to live for weeks and months under those conditions.

Q. Mr. Fuller, what do you say as to the longevity of the germs of Asiatic cholera under the conditions mentioned in your last question?

A. The life history of the germs of Asiatic cholera under the conditions mentioned is less accurately known than in the case of the typhoid fever germs. Generally speaking, however,

it is my opinion that there is not any very great difference in the life history of the germs of the two diseases, under the conditions stated in the question.

Q. Mr. Fuller, in your judgment, what is the influence or effect upon the sewage discharged into the Des Plaines river at Lockport, of the dilution which, under existing conditions, takes place in the Illinois river, viewing this question from the standpoint of a hygienic or sanitary character of the Illinois river water, as it enters the Mississippi river at Grafton?

A. The dilution of the Chicago sewage, as it flows from Lockport to Grafton, by the waters of the Illinois river and tributaries, is a very variable proposition. At times the dilution of the contents of the Chicago Drainage Canal by the flow of the Illinois river and its tributaries, is very considerable. At other times the volume of flow of the Chicago Drainage Canal exceeds the flow of the Illinois river, this being true particularly in its upper reaches. There consequently results at times a dilution of the Chicago sewage by the waters of the Illinois river, and other times a dilution of the Illinois river by the contents of the Chicago Drainage Canal. Dilution at best does not destroy disease germs of infectious matter. Its effect is to minimize the danger to those who may drink of the water so diluted. One effect of the dilution existing in the Illinois river at low stages is to bring to Grafton more quickly than would otherwise be the case, injurious matter entering the Illinois river at points along the route of its flow, and also entering the Illinois river from cities and towns located upon the tributaries to that river.

Q. Mr. Fuller, in your judgment, what is the significance of the ponds and of the dams and of the slack water stretches which are found on the Illinois river, regarding the hygienic or sanitary character of the diluted Chicago sewage flowing from Lockport to Grafton?

A. The most significant feature of these so-called lakes, dams and slack water stretches is the low velocity of flow of the water, at times of low stages of the Illinois river. There are a good many days in the course of a year when these velocities at the places above referred to are so low that deposition takes place to a considerable degree, of the bacteria

and other matters suspended in the water, and which to a large degree are derived from the contents of the Chicago Drainage Canal. The deposition of these bacteria, including those of infectious diseases like typhoid fever, does not mean their permanent elimination and removal from the flowing water. The reason of this is that as they reach the bottom and lie upon the bed of the stream they are disturbed from time to time, due to changes in velocity of stream flow, such as caused by moderate rains, or by the passage of boats or the action of the wind and the like. The resulting disturbances cause the bacteria to leave the bed of the stream in which they may rest for some time, bringing about a return of those bacteria to the flowing water. In this way the germs of disease may pass from the Chicago drainage canal at Lockport to the mouth of the Illinois river at Grafton.

Q. Mr. Fuller, is it or is it not your opinion that typhoid fever germs disappearing from the flowing stream and becoming deposited in the bed, are able to live there for weeks or months?

A. I think that they are able to live for weeks and months.

Q. Mr. Fuller, I will get you to state if in your judgment it is possible, that the water of the Illinois river as it flows into the Mississippi may sometimes be richer in typhoid fever germs derived from the sanitary district of Chicago and coming through the drainage canal, than was that portion of the water drawn from the drainage canal when it flowed over the Bear Trap Dam?

A. In my judgment such a condition of affairs at times is not only possible but probable.

Q. Why?

A. Such a condition of affairs may arise and at times probably does arise through the disturbances of the sediment lying upon the bed of the stream in places, which sediment may and undoubtedly at times does contain relatively large numbers of typhoid fever germs. As these typhoid fever germs are returned to the flowing stream from their position in the bed of the river there is effected an accumulated result, whereby at times at least the waters of the Illinois river flowing to Grafton, may discharge

the concentrated essence of the infection of Chicago sewage, by taking in the manner above described, portions of the infection coming from many days' flow of the drainage canal into the Illinois river.

Q. Mr. Fuller, I will get you to state if you know of any cases excepting storage reservoirs connected with public water supplies, in which sedimentation is employed for the purification of sewage or sewage polluted water without any provision having been made for the removal of the sedimented materials, so that these shall not find their way back to the flowing stream?

A. I know of no such instance, and it is obvious that if means are not provided for the removal of sedimented materials from time to time under proper conditions so that they will not re-enter the water as it leaves those basins, then the object and purpose of the settling basins largely fails.

Q. Mr. Fuller, do you or do you not consider that all existing circumstances and conditions from Lockport to Grafton, taken separately or together, are sufficient to prevent at all times the pollution and infection coming from the Chicago Sanitary District and entering the Mississippi valley at Lockport, from reaching the Mississippi river at Grafton?

A. I believe that those conditions are not sufficient to prevent at all times infected materials coming through the Chicago drainage canal and entering the Mississippi valley at Lockport, from reaching the Mississippi river at Grafton.

Q. Mr. Fuller, do you know how far it is from Grafton to the Chain of Rocks, water tower?

A. About 29 miles.

Q. Do you know how long a time is required for the Mississippi river to flow from Grafton to the chain of rocks?

A. It is a fraction of one day.

Q. That is in the ordinary stage of water?

A. Yes, sir.

Q. Mr. Fuller, is it or is it not possible, in your judgment, for the Illinois river water entering at Grafton the Mississippi river, which in turn is joined with the Missouri river six miles above the Chain of Rocks, to flow past the Chain of Rocks with-

out some of the Illinois river water ordinarily entering the intake tower of the St. Louis waterworks?

A. I don't believe that it is possible for the Illinois river water to flow by the Chain of Rocks without some of it ordinarily entering the Chain of Rocks intake tower of the St. Louis waterworks.

Q. Mr. Fuller, in view of all the facts and conditions as you know them, do you or do you not consider that the sewage of the Chicago Sanitary District pollutes and infects the water of the Mississippi river along the Missouri shore, and especially at the Chain of Rocks intake tower of the St. Louis waterworks, to such an extent that it makes the Mississippi river water less safe for drinking and domestic purposes than it was before the opening of the drainage canal?

A. It is my judgment that it does.

Q. Mr. Fuller, assuming that during the three years before and the three years after the opening of the Chicago drainage canal, the total number of typhoid fever deaths so far as can be learned, was about the same on the watershed of the Mississippi river above the intake tower of the St. Louis waterworks at the Chain of Rocks, exclusive of the Sanitary District of Chicago, and that there were 337, 509 and 801 typhoid deaths in 1900, 1901 and 1902, respectively, making a total of 1,647 typhoid deaths for these three years in the city of Chicago since the opening of said canal; state whether or not the said deaths in Chicago have, in your judgment, had any influence on the typhoid fever mortality of the city of St. Louis, and if so, what?

A. It is my judgment that under the conditions assumed in the question, the typhoid infection coming from Chicago and passing through the drainage canal by way of the Des Plaines and the Illinois rivers to the Mississippi river and to the intake tower at the Chain of Rocks, of the St. Louis waterworks, did have an influence upon the typhoid fever death rate in the city of St. Louis, and that it is the cause of the principal portion of the increase during the past three years.

Q. Mr. Fuller, assuming that the population of the sanitary district of Chicago grows larger, and that the amount of

Lake Michigan water and of the sewage sent down the drainage canal and on into the Mississippi river under conditions corresponding in method of procedure to those which prevail today on the Des Plaines and Illinois rivers, thereby increasing the amount of infected sewage entering the Mississippi watershed, what effect could such future growth of population in Chicago, and such future increase in added pollution to the Mississippi river waters, reasonably be expected to have upon the sanitary quality of the water of the Mississippi river in its raw condition, arriving on the shores of the State of Missouri below the mouth of the Illinois river and especially at the intake of the St. Louis waterworks at the Chain of Rocks?

A. Under the conditions assumed in the question it is my opinion that the water in the Mississippi river along the Missouri shore, especially at the Chain of Rocks, intake tower St. Louis waterworks, in its raw condition, would be rendered less safe than at the present time, due to the increased amount of infection entering the Mississippi watershed from Chicago and to the shorter interval of time required for the passage of that sewage from Chicago to the points considered, on the Missouri shore of the Mississippi river.

Q. Mr. Fuller, what effect, if any, in your judgment would the increasing amount of sewage from the sanitary district, coming through the drainage canal into the Illinois river in future, caused by the growth of population in the sanitary district of Chicago, have upon the Illinois river and the Mississippi river at low water stages?

A. It would make it a much less safe water generally speaking, than at the present time, and it is quite possible that looking far enough into the future, that this amount of pollution would become sufficient to exceed the oxygen and to make it in many ways resemble an open sewer; that is to say, it will be a stagnant pool, resembling sewage rather than a live, natural water containing atmospheric oxygen.

Q. Mr. Fuller, I will get you to state if in your judgment the increased sewage coming into the Illinois river by way of the drainage canal and thence into the Mississippi, now, and in the future, would add any difficulties, or increase any cause to

the problem of filtering or otherwise purifying the water of, and furnishing with safe water, the city of St. Louis?

A. In my judgment the increased amount of infection coming into the Mississippi river from the city of Chicago's sewage at the present time makes an added responsibility as regards the treatment of that water, to make it perfectly safe and wholesome as supplied to the citizens of St. Louis. Such treatment of the water would involve, I think, at the present time, more responsibility, and in a financial way, it would be shown by the greater expense of supervision of a filtration plant, and the added cost of supplies used in connection with the operation of filtration works, especially at times of low water. It would also mean that such filtration works, if adopted, would be operated from time to time, if not regularly, at lower rates of filtration than if this increased infection were absent. The significance of this is that by reducing the rate of filtration, that a larger plant would be required, and hence a more expensive installation for filtration works, to purify the same quantity of water than in the instance of water without this added infectious matter.

Looking some distance into the future and considering the various centers of population naturally tributary to the Mississippi river at St. Louis, the Missouri and Illinois rivers, but excluding the Chicago Sanitary District, it is certain that there will ultimately come a time when single filtration can hardly be expected to produce a satisfactory quality of water with its source at the Chain of Rocks, intake tower. When that time will come it is difficult to state specifically, as it will depend upon the rate of growth of population in the communities situated upon the watershed of the Mississippi, Illinois and Missouri rivers, exclusive of the Sanitary District of Chicago.

Whatever the rate of growth may be in the communities situated upon the watershed of the Mississippi river above St. Louis, independent of the city of Chicago, it is certain that the added infection of the Mississippi water at the St. Louis intake due to the Chicago sewage, will hasten the day when single filtration at St. Louis will prove unsatisfactory, and when it will be necessary to give attention either to double filtration or

to other methods, involving increased expense and increased responsibility." (Fuller's testimony, Vol. 3, pp. 2607 to 2624.)

DR. HERBERT E. SMITH: In rebuttal, Dr. Herbert E. Smith, on the chemical condition of the waters in question, said in part, as follows:

"Now, Doctor, I show you tables 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, introduced and read in evidence by Professor Kinnicutt, these tables showing the mean of Professor Jordan's and Palmer's result, May to December, 1899, in the Illinois river, Joliet, north of Jackson street; Ottawa, LaSalle, Henry, Averyville, Pekin, Havana, Beardstown, Kampsville and Grafton. I will ask you to state what conclusions you draw from these tables, and what these tables of mean results show with reference to the condition of the stream at these points, as to its average pollution at all times of the year?

A. These results show the average composition of the samples of water at the times and places at which they were collected. The several samples show that in the upper portion of the water way there was a very high chemical and bacterial pollution; that there was a gradual diminution in the amounts of the various chemical constituents in the progress down the river, and that there were certain places where there was an increase in these constituents; the figures for the samples taken at Grafton show that there was in those samples a very considerable evidence of sewage contamination still remaining. There was some variation in this diagram, also in bacteria, the number at the Grafton station being somewhat higher than at the Kampsville station, for instance.

The tables fail to show the true conditions of the river at these several stations at all times because a sample taken from a running stream, from time to time, can not of course show the composition of the river at that place at other times, and further, there is no evidence in these tables that the samples taken at the time they were taken were proportional to the flow in the river, and obviously they would represent a different proportion of the constituents in the river at times of flood from what they

would at the time of low water, the samples being of the same size.

Q. I show you tables 57 to 64, inclusive, Doctor, introduced in evidence by Professor Kinnicutt, and based upon the mean of Jordan and Palmer's results, from January to June, 1900, and the following points in the Illinois river: Table 53, Joliet; table 54, Morris; table 55, Ottawa; table 56, LaSalle; table 57, Henry; table 58, Averyville; table 59, Wesley City; table 60, Pekin; table 61, Havana; table 62, Beardstown; table 63, Kampsville, and table 64 at Grafton, and ask you to examine these tables and state whether or not from the mean results shown by them positive conclusions can be drawn as to the sanitary condition of the water in the river at those points at all times in the year?

A. In my opinion these tables do not show the condition of the water in the river at the several points at all times of the year for the reason that the samples were taken occasionally and not continuously; that they did not as far as the tables show, take into consideration the flow at the time the samples were taken, and that in general an average of this sort can not show the condition of the stream at other times than those at which the samples were taken.

Q. Doctor, I will show you tables 1 to 12, inclusive, introduced in evidence by Professor Kinnicutt, as giving the mean of Doctors Long and Palmer's results for May, June, July and August, 1899, and 13 to 24, inclusive, the mean of Doctors Long and Palmer's results for May, June, July and August, 1900, and will ask you to state what, in your opinion, is the value of these tables as to their showing the sanitary condition of the water in the Illinois river at all times of the year?

A. In my opinion these tables fail to show the condition of the water in the river at all times and seasons for similar reasons stated in my answer to your last question.

Q. Doctor, have you examined the individual results upon which these averages were based?

A. I have.

Q. State whether or not you have noticed any individual samples, the determination of which deviate markedly from the average in the evidence of sewage pollution?

A. In my examination of the individual results upon which these tables of averages are based, I have noted many results which deviate widely from the average.

As an illustration, on table 101 in the Streams of Examination, which relates to the analysis of the Illinois river at Grafton during 1899, I find that on November 8th, the samples showed a chlorine of 4 parts per million; on May 31st of 3.7 parts per million, while the average given in Professor Kinnicutt's table of the results obtained at this point is 18.4 parts per million.

I would say that on that particular table there were 17 samples, more than half, therefore, that were above the average in chlorine, and there were 16 that were below the average.

With regard to the free ammonia, I find that on December 6th there was present 1.12 parts per million, and on June 21st, .04 parts per million, while the average of all the determinations at that point gave 0.23. There were 12 samples above the average and 21 samples below the average.

In the same tables, the figures for suspended matter, or suspended residue referred to in another place as suspended solids, was, on May 31st, 873.8 parts per million, and on October 11th was 1 part per million, while the average of all the determinations is given as 82.4.

These indicate some of the ranges which I have noted, and similar discrepancies are found in the other tables.

Q. Doctor, state whether or not and in what way, if any, true conditions fail to be displayed from the tables of averages such as these about which we have been testifying?

A. The general average does not show a true condition because the general average can only relate to the conditions at the times and places when and where the samples were taken.

In a stream of running water, which varies in volume, it is very important that the samples should be taken in such volume as will indicate the relative flow at the time the samples are taken.

For another reason a sewage contaminated stream varies greatly from time to time in its content of impurity, depending largely upon the irregularities in the discharge of the sewage, at one time the sewage being of a certain character and at an-

other time differing widely from it, either because of the sort of discharge of materials from factories or manufacturing establishments or something of that sort, or from the variations ... are found in the flow of sewage in the matter from houses at or during different hours of the day. Moreover, there is a very marked difference in the flow of streams, due to the variable rainfall at different seasons and times. This has the effect not only of increasing the volume of the flow, diluting it at one time, the constituents over the conditions which prevail at another time, but the larger flow tends to bring down the stream accumulated materials and form movable deposits, both upon the watershed and in the stream itself. For these various reasons an average result can not show the condition of the stream at all times.

Q. Doctor, in the present developed state of sanitary science, state whether or not a table of averages, such as were introduced by Professor Kinnicutt, are considered by the scientists as sufficient to enable one to make a competent determination of the sanitary condition of water in a running stream?

A. In my opinion the tables of averages which are referred to as having been introduced by Professor Kinnicutt do not form a competent basis in the present condition of sanitary science to permit a definite opinion as to the sanitary condition of the stream to which they relate.

Q. Upon what do you base your last answer?

A. I base my answer first upon the reasons already assigned why a general average can not be taken as representing the general character of the stream to which they relate at all times.

And further, I base my opinion upon my belief that chemical analyses do not and can not show all the evidences of dangerous pollution which may exist in a stream. The chemical analysis is addressed to the deduction and determination of certain elements which are useful in determining the presence or not of sewage in a stream, but in the present state of the science it is impossible to decide whether certain results are or are not evidence of sewage contamination; and further, that there are certain ingredients which may be present in a stream coming from sewage and which are of material importance

which are not revealed at all by the chemical analysis. In my opinion, therefore, the chemical analysis alone is not a sufficient basis to decide whether a sewage polluted stream contains the dangerous elements of sewage.

Further, I base my opinion upon my belief that in the present state of sanitary science the bacteriological analysis does not reveal in all cases the presences of those constituents of sewage which are dangerous.

And, further, I would state that in the present condition of sanitary science, neither the chemical nor the bacteriological analysis alone, nor both together, can be absolutely relied upon to show the presence in a stream of those substances which may come from sewage and do come from sewage and which are dangerous.

Q. Doctor, you have examined the book, known as Streams Examination, all the tables from which were introduced in evidence in this case, have you?

A. I have.

Q. In giving your answer to the last questions have you considered the tables contained in this book, known as Streams Examination, and what you have learned from it?

A. In answering your questions relating to the analysis I have taken into consideration the information which I obtained by consideration of the tables in the book known as Streams Examination.

Q. From your examination of all the tables contained in this book known as Streams Examination, and which said tables have been introduced in evidence, and from the tables introduced in evidence by Professor Kinnicutt state whether or not you are able to say that all the harmful elements and disease producing bacteria discharged into the canal at Chicago have become eliminated from the Illinois river by the time that it reaches Grafton?

A. From my examination of the results given in the tables in the book, Streams Examination, and of the tables of averages based thereon, I would say that I am unable to state that they show that all injurious ingredients have been eliminated from the sewage.

Q. Are you acquainted with the extent of the population residing upon the watershed of the Illinois river, the rural and the urban population?

A. I have seen the figures, yes, sir.

Q. Have you acquainted yourself, Doctor, with the relative amount of sewage that is immediately discharged into the Illinois river for the various periods mentioned, upon the Des Plaines and upon the banks of its tributaries, exclusive of the Sanitary District of Chicago?

A. I have examined the figures showing the amount of sewage discharged into the Illinois river at various points upon its course.

Q. Doctor, have you made yourself acquainted with the velocity flow of the Illinois river from Chicago to the Mississippi?

A. I have examined figures showing the flow of the Illinois river at the points mentioned.

Q. The figures that you examined in reference to that were those determined by Professor Van Ornum and Isham Randolph, are they not?

A. I understood that they were the figures introduced by the gentlemen named.

Q. Taking into consideration, Doctor, the extent of the urban population residing upon the watershed of the Illinois river, exclusive of the city of Chicago, and taking into consideration the usual volume of water passing down that river, together with the added volume of 250,000 cubic feet per minute, from Chicago, state whether or not in your opinion the chemical and bacterial results shown upon the tables contained in Streams Examination and the results upon the tables introduced in evidence by Professor Kinnicutt show the sanitary chemical and bacterial condition of the water in the Illinois river to be higher or lower from a sanitary standpoint than ordinarily exists in rivers of this kind having similar population and flowing similar volumes of water?

A. Taking into consideration the urban population upon the several watersheds tributary to the Illinois river, exclusive of that of the Chicago Sanitary District, I will state it is my

opinion that the results shewn in the tables in the examination of streams and in the tables of averages based upon them, show that at the times when these samples were taken there was more evidence of sewage than I should expect in a river of this size and population.

Q. State whether or not in your opinion, Doctor, the chemical and bacterial data found in the tables contained in Streams Examination, and the tables introduced in evidence by Professor Kinnicutt, show more or less any such bacterial and chemical constituents which are usually considered as evidence of sewage than which you would expect in event the sewage from the sanitary district of Chicago was not discharged into that river, the same volume of water flowing down the river in each event?

A. In my opinion the tables referred to do show that there was at the times when the samples were taken more evidence of sewage contamination than I should expect to find from the urban population on the watersheds tributary to the Illinois river, exclusive of the Chicago Sanitary District."

(H. E. Smith's testimony, Vol. 8, pp. 7685-7694.)

Of the dams on the Illinois river and their effect on the water, Dr. Smith said:

"Q. Assume, professor, that a larger portion of the sewage of Chicago passed through the old Illinois and Michigan Canal in a more concentrated condition than it does through the drainage canal; assuming further that during the greater part of the year, under such conditions the water in the Illinois river, practically from Grafton to Henry, was covered with a green scum as though in a quiescent condition, and as described by some of the fishermen on the river, who testified for respondent, stood in a stagnant condition with no perceivable current, such that when a skiff would be rowed across it, it would separate the green scum and leave the line of separation distinct and visible for a great distance behind; that if a chunk should be thrown in the river it was as liable to float up stream as down stream, depending altogether upon the direction of the wind; that the five dams practically retarded the progress of the water down the stream; that in order to protect navigation it was necessary for them to

erect banks on top of the dam so as to increase the height of the water above the dam; assuming further than since the opening of the canal that there has been a continuous current at all times of the year, both above, below and over the respective dams. State whether or not upon these assumptions the facilities for removal of the pathogenic bacteria and harmful ingredients of the water coming from the sewage of Chicago were not better prior to the opening of the drainage canal than subsequent to that time, and also is it not a fact that such facilities for removal are not and can not be displayed by the tables of averages and by the tables themselves contained in Streams Examinations and introduced by Professor Kinnicutt and which you have examined, the volume of water that passed through the Illinois and ranging from 19,000 to 49,000 cubic feet per minute, and the volume of water passing through the drainage canal since its opening ranging from 200,000 to 250,000 cubic feet per minute?

"A. In answering your question I have taken into consideration the assumptions and statements made and would state it as my opinion that the conditions assumed and stated to be present in the river prior to the opening of the drainage canal were such as would afford greater facilities for the removal of pathogenic organisms which exist since the opening of that canal.

"And, further, I would state as my opinion that the data furnished by the tables in the book of Streams Examination, and the tables based thereon, do not furnish data for determining the extent to which these pathogenic organisms have been removed." (H. S. Smith, Vol. 8, pp. 7695-7696.)

HARMFUL SUBSTANCES PASS FROM CHICAGO TO ST. LOUIS.

"Q. Speaking as an expert in the interpretation of sanitary water analysis, bacterial analysis and all other means of determining the sanitary condition of a running stream, I will ask you to state your opinion concerning the purification of the sewage of Chicago at the time it passes out of the drainage canal.

"A. Basing my opinion upon the results of the chemical and bacteriological analysis which have been furnished, and the tables referred to, and upon other data within my knowledge bearing upon the subject I would state it as my opinion that the sewage is not purified from the harmful agents at the time it is discharged from the drainage canal.

"Q. Assuming that the water passes from the city of Chicago through the canal into the DesPlaines river, and down the Illinois to the Mississippi, past the Chain of Rocks at St. Louis, within from ten to twenty days, state your opinion as an expert on water supply for cities and towns as to whether or not the waters of the Mississippi river at the Chain of Rocks are less available for drinking purposes and more liable to contain water borne diseases such as typhoid now than it did before the sewage of the Sanitary District of Chicago was borne into the drainage canal and through it to the Illinois river?

"A. I will state it as my opinion based upon the facts which you have stated, that the water at the Chain of Rocks is less available for sanitary use than it was before the opening of the sanitary canal, and that there is a very much greater liability of the infection with typhoid bacilli of persons drawing water from that point in the river.

"Q. Doctor, Professor Kinnicutt, in his direct examination by counsel for respondents, was asked this question, and I desire to ask it of you: If an increased volume of water in the Illinois river, by the addition of the water of the drainage canal at the rate of 250,000 cubic feet per minute would make an increased speed in the current of the Illinois river, would that increase in said current have any effect in increasing or diminishing the liability to typhoid and other water borne diseases on the part of the inhabitants of the State of Missouri using the water of the Mississippi river for drinking purposes below the month of the Illinois?

"A. In my opinion an increase in the flow of the Illinois river as assumed would very largely increase the liability of the infection of persons drawing a water supply consisting in whole or part of water from the Illinois river." (H. E. Smith, Vol. 8, pp. 7697-8.)

INFORMATION NECESSARY TO ENABLE SANITARIANS TO DETERMINE CONDITION OF WATER.

"Q. Doctor, please state in a general way as a sanitarian and epidemiologist what is necessary in order to enable one to pass intelligent judgment upon the sanitary character of water?

"A. To form a competent opinion as to the sanitary condition of a water and its suitability for use and as a supply of drinking water, one should avail himself of all knowledge obtainable on the subject. A chemical examination may give such results as would indicate that the water is sewage polluted. The discovery of such evidence must always make such a water to be regarded with suspicion. To decide the importance of the suspicion one must determine the condition and the extent as far as possible from other means as to the extent and nature of the pollution.

"There are cases, however, which the chemical analysis will fail to give positive data as to the presence of sewage even when it is undoubtedly present as shown by other data.

"Regarding the bacteriological analysis, I would say that it is frequently possible to obtain results which also indicate the presence of sewage contamination and that such evidence must always render that water suspicious, and that the importance of the suspicion must be determined by a thorough examination as to the source and nature of the source of the pollution, but there are cases in which the results of the bacteriological analysis will not disclose the presence of the ingredients of sewage when it is known by other tests that they are present.

"Indeed, the bacteriological tests have frequently failed to show the evidence of sewage contamination positive in streams which were known to have received sewage contamination. When one must depend upon such data for the determination of the suitability of a proposed water supply, one must use not only the evidence of the chemical and bacteriological examinations, but all data relating to the surroundings of the source from which the water comes.

"In determining, however, whether a water in use has been a subject of sewage pollution, unquestionably the most positive way of obtaining evidence is a careful study of the effects which have been produced by the water upon the persons who have used it. Where a large community uses a water which has been sewage polluted and the injurious ingredients of the sewage still exist in the water it is inevitably shown in its results upon the health of the people. This is so much the case that the statistics of typhoid fever in a community is on the whole the best evidence which pertains to the fact of sewage pollution.

"I would state, therefore, that in my opinion the best test which can be applied to decide whether a given water supply has been infected by sewage is to study the typhoid statistics of the community using the water." (H. E. Smith, Vol. 8, pp. 7701-7702.)

TYPHOID LIVE IN SEDIMENT SIXTY DAYS.

"Q. As sanitary expert, availing yourself of all the chemical and bacterial knowledge which is available to you, what is your opinion as to whether typhoid bacilli living in the sediment of a polluted stream for the period of sixty days would be able to produce typhoid fever if taken into the human system?

"A. I would state it very positively as my opinion that typhoid bacilli living in the sediment of a polluted stream for the period of sixty days would be able to produce typhoid fever if taken into the human system.

"Q. What is your opinion as a sanitary expert as to whether pollution and typhoid fever bacilli coming from the sewers of Chicago, through the drainage canal, deposited in the bottom of the Des Plaines and Illinois rivers can remain there for the period of from thirty to sixty days and yet retain their dangerous qualities as well as pathogenicity?

"A. I will state it as my opinion that I believe when typhoi bacilli are deposited on the bottom of the DesPlaines or Illinois river, between Chicago and Peoria for a period of thirty or forty days they might retain their dangerous qualities as well as their pathogenicity, for I know of nothing which would

make it certain that such an organism would meet with any material which would be certainly destructive to it under such conditions." (H. E. Smith, Vol. 8, pp. 7702-3.)

ZONE OF PURIFICATION IN A POLLUTED STREAM.

"Q. From the studies that you have made upon the question of self-purification of running streams, I will ask you to state what is your opinion as to the ability of a running stream to purify itself so as to be free from all pathogenic bacteria that may be discharged therein at a given point so that the zone of purification may be determined to exist at a certain point, and that this given point may apply under all conditions, local and otherwise, at all velocities and volumes of water, all temperatures of weather and seasons of the year?

"A. The conditions affecting the purification of streams from the materials introduced by sewage are so complex that in my opinion it would be impossible by the ordinary methods to determine at what point in the river the purification was always effected, the only way which I can suggest as being entirely satisfactory for the solution of such a problem is the study of the results of the use of such a water by a considerable community. If these fail to show any evidence of a deleterious effect produced by the water, and especially if they fail to show any evidence of typhoid fever, that typhoid fever has been produced by the use of the water, I should think we might reasonably conclude that that point was without the zone of danger during the time of the experiment, but owing to the fact that the chief deleterious constituents of sewage are living organisms, that they may be protected at certain times and in certain numbers by being enveloped in solid materials which would protect them from the influences ordinarily working against them in streams, it would be impossible to predict with certainty that at some other time than the time of the experiment the water would be perfectly safe at that point.

"It is important to recognize in the question of sewage pollution that the chief injurious ingredients are living organisms and the question of dilution does not come into the discussion

to anything like the extent that would be the case if the injurious ingredients were inert chemical substances.

"If this were the case it is perfectly certain that we could reach a point where the most harmful chemical substances could be diluted to such a point that it does in any given amount of water in the stream would be without effect upon the living persons, but with regard to a living organism we have to recognize the point that the dilution does not effect the individual organisms, but only its dissemination through the water, and that, therefore, it is possible to find in one portion of the water something that would be deleterious while in other adjacent units of the same size there might not be any." (H. E. Smith, Vol. 8, pp. 7706-7707.)

LONGEVITY OF TYPHOID FEVER GERMS.

"Q. Doctor, state whether or not you have examined the evidence introduced by Doctors Zeit, Jordan and Russell with reference to certain experiments conducted by the use of parchment sacs for the purpose of determining the longevity of typhoid bacilli in the waters of the canal and the Illinois river so as to exemplify true conditions in that water?

"A. I have.

"Q. Have you familiarized yourself with that testimony in this connection?

"A. In a general way I have.

"Q. State, Doctor, whether or not in your opinion these experiments so conducted by Doctors Zeit, Jordan and Russell exemplify actual conditions existing in the running waters of the canal and the Illinois river with reference to the longevity of the typhoid bacilli?

"A. In my opinion these experiments do not exemplify the true conditions, the conditions which exist in the water of the drainage canal with relation to the life of the typhoid bacilli discharged into that as a part of the sewage.

"Q. Upon what do you base this opinion?

"A. The opinion is based on several points: First, the introduction of typhoid bacilli in an artificial culture in such a

quantity of sewage enclosed in a parchment sac and protect it. This does not simulate the condition which would exist in the case of typhoid bacilli discharged into sewage and coming from a patient suffering from typhoid fever, in which case the organisms might readily be and frequently are enclosed in fecal masses. Further, the condition of the bacilli in this sac is quite different from that which they would be under if they were free in the stream where they would be free to settle, deposited in the sediment they might then become protected from the influence of the sewage upon them.

"Q. State whether or not in your opinion the fact that the bacterial and the chemical condition of the running water in the canal and river remain the same from one end of the day to the other, at the point where these parchment sacs may have been suspended in the water?

"A. In my opinion the condition of the water would frequently change at any one spot owing, as I have said previously in my testimony, to the changeable condition of the discharge which we find coming from the sewers in Chicago.

"Q. Would the fact that there is a different volume or quantity of sewage passing down at night than at day have any effect upon the chemical and bacterial changes of the water?

"A. Yes, the difference in the flow between day and night would make a difference in the composition of the sewage water at any one place, and further, the flow at night is very different in composition from the flow during the day.

"Q. Might not the fact, Doctor, that these bacteria were detained at one point in the parchment sac be harmful to them while if not so retained in the parchment sac they would pass further down the river in a more favorable media and their longevity be preserved?

"A. Yes, sir. If the destructive action which was found in these cases to be exerted upon the bacilli was due in any way to the concentration of the sewage, the further the bacilli moved down the stream the less they would be subjected to this because of the increased dilution in the lower stretches of the river.

"Q. Doctor, state whether or not in your opinion you know of any bacteriologists, epidemiologists or sanitarians who have

limited the longevity of the life of the typhoid germ either in sewage or sewage polluted water to less than six days?

"A. I know of no previous experiments which were of such a character as to warrant the experimenters for making such an assertion.

"Q. Do you know of any expert as having written any article or expressed an opinion that the longevity of the typhoid fever germ in sewage or polluted water is within the limit of six days?

"A. I do not recall any such limitation placed by any one.

"Q. I will ask you to state whether or not, Doctor, from your researches in sanitary science and epidemiological work the opinions based upon the experiments of Doctors Zeit, Jordan and Russell wherein the longevity of the typhoid germ is limited to within six days do not stand by themselves and alone from all opinions that have been expressed and all determinations and observations that have been made by reputable sanitarians?

"A. As far as I know this period of time is shorter than given by other authorities. More experiments of this sort have demonstrated that sewage is in concentrated form detrimental to the life of the typhoid bacteria, but the length of time which bacteria have lived in sewage of the different experiments have been so various that I do not recall a limitation expressed by any standard authorities on this subject.

"Q. Doctor, I will ask you if you know of any instance where typhoid fever germs are known to have lived in sewage longer than six days?

"A. Yes, there are published records of experiments showing the longer period than six days. To refresh my memory a moment the one set of experiments that I have in mind are those of Dr. Horrock's, who showed that typhoid bacilli survived in unsterilized sewage a period of fourteen days and there have been other experiments made by different experimenters on this point.

"As I state, I do not know of any one who has felt justified, as the result of these experiments, of limiting the period which typhoid bacilli might survive in sewage when they were intro-

duced in what we might speak of as natural media and under natural conditions.

"Q. You mean by unsterilized sewage ordinary sewage?

"A. Yes, sir, as contrasted with that in which other forms of bacteria have been destroyed before the other experiments have begun.

"Q. Doctor, in his testimony under date of March 1st, last, Professor E. G. Smith was asked by counsel for defendant the following question: 'Assuming that the only pollution of the waters of the Mississippi river above the intake of the St. Louis Water Works derived from the sanitary district of Chicago, and having in mind a large amount of typhoid fever in Chicago, do you or do you not believe that infectious and dangerous pollution might, under existing conditions, find its way into the water supply of the city of St. Louis,' answered as follows: 'The evidence is already introduced in this case, both chemical and bacteriological, showing, in my opinion, some conclusions that the agency of self-purification above in this stream have practically transformed the sewagic matters from the city of Chicago before they reach Grafton, reducing the river at that point practically to the conditions of the streams, and the positive results secured in the experiments of Doctors Zeit, Jordan and Russell upon the liability of the typhoid fever germ in the polluted water of this stream, I do not believe that infected and dangerous pollution might, under existing conditions, find its way into the water supply of the city of St. Louis.' I desire to ask you this same question, and ask you to take into consideration all of the matters contained in the tables found in Streams Examination, introduced in evidence, the tables introduced by Professor Kinnicutt, the tables introduced by Professor Jordan, outside of such tables are are prepared by him and found in Streams Examination, and also to take into consideration what bearing, if any, the experiments of Doctors Zeit, Jordan and Russell have upon actual conditions, and state whether or not in your opinion, under existing conditions, the infected and dangerous matter coming from the sewage of Chicago would find its way into the water supply of the city of St. Louis?

"A. Taking into consideration the various data to which you have called my attention, I would state that I have been able to find no evidence which to my mind is conclusive that the agencies at work in the stream are adequate to destroy the typhoid bacilli which undoubtedly are introduced into the sewage of Chicago and through it into the Illinois river, and, therefore, I believe that dangerous and infected pollution might reach the intake of the St. Louis Water Works.

"Q. Under the same assumptions, Doctor, as stated in the last question, do you or do you not believe that such infection and dangerous polluting matters coming from the sewers of Chicago do, under existing conditions, find their way into the water supply of the city of St. Louis?

"A. In answer to your question, I would state that, considering all the data which I have been able to consider as bearing upon this problem, I believe that typhoid bacilli from the sewage of Chicago have reached the intake of the St. Louis Water Works.

"Q. Doctor, Professor Smith, in his testimony under date of March 1st, was asked by counsel for defendants the following question: 'Considering your personal knowledge as a sanitary expert of the typhoid conditions in the drainage district, the existing conditions in said city as to sewers and offalls there and the amount of sewage and all existing conditions of the Des Plaines, Illinois and Mississippi and Missouri rivers, and all the conditions existing upon the watersheds of these streams and the tributaries thereof, and all conditions as to the water supply of the city of St. Louis, would you or would you not, beyond a reasonable doubt, attribute the principal portion of the increase of typhoid fever of St. Louis to the infected sewage of the Sanitary District of Chicago, assuming that there has been an increase of typhoid in St. Louis since the opening of the drainage canal?' Now, I will ask you to state, considering your knowledge as a sanitary expert of the typhoid conditions in the Sanitary District of Chicago, your knowledge of the pollution and the amount of sewage deposited into the canal, and thence into the Illinois river from the sanitary district, under all existing conditions, on the watershed of the streams of the Missis-

sippi river and its tributaries above the Chain of Rocks, and all existing conditions as to the water supply of the city of St. Louis and the general sanitary conditions existing in St. Louis, do you or do you not, beyond a reasonable doubt, attribute the principal portion of the increase in typhoid fever in St. Louis to the infected sewage of the Sanitary District of Chicago, also taking into consideration the results from the various analyses made by analysts, who have testified in this case, as shown by the tables contained in the book known as Streams Examination, the report of the State Board of Health of the State of Illinois, and the tables introduced by Professor Kinnicutt and the tables introduced by Professor Jordan and the special experiments carried on by Professors Zeit, Jordan and Russell with reference to the longevity of the typhoid germ as contained in parchment sacs?

"A. I consider the problems involved in your question and would state that in my opinion the data available, especially those relating to the typhoid fever conditions upon the watershed of the Mississippi and Missouri rivers above the intake of the St. Louis Water Works, and the data concerning the occurrence of typhoid fever in the Chicago Sanitary District, are sufficient to demonstrate that the increase in typhoid fever has been due in considerable part at least to infection from the Chicago sewage." (H. E. Smith, Vol. 8, pp. 7709 to 7716, inclusive.)

TYPHOID CONDITIONS AT ST. LOUIS AND THE CAUSE.

"Q. I will ask you to state, Doctor, whether or not you have examined the evidence introduced in this case upon the part of the complainant and the defendants as to the typhoid mortality in the city of St. Louis for the last six or eight years?

"A. I have.

"Q. I will ask you to state, Doctor, bearing in mind the fact that in 1895 the intake of the water works of the city of St. Louis was changed from Bissell Point to the Chain of Rocks above the pollution of the Mississippi river by the city of St. Louis, to state whether in your opinion you consider it competent to compare the typhoid fever mortality of St. Louis previous to 1896 with that subsequent to that time in order to de-

termine accurately and correctly whether or not an increase of typhoid deaths has taken place in the city of St. Louis since the opening of the drainage canal?

"A. In reply I would state that it is my belief that a comparison of the typhoid fever death rates in St. Louis during the two periods, 1896 to 1899, inclusive, and 1900 to 1903, inclusive, is a competent method of deciding whether there has been an increase of typhoid fever in St. Louis. And, further, I will state that in my belief this is the best method of testing the question as to whether there has been a change in the quality of the drinking water supplied to St. Louis with reference to its infection with typhoid fever.

"Q. You mean by your answer that the manner suggested by you in the answer is the best method?

"A. I mean that the comparison of the typhoid death rate in St. Louis for the two periods is the best method of ascertaining the conditions of the drinking water of St. Louis with reference to this period, of course using in connection with that the data concerning the upper watershed.

"Q. I will ask you to state, Doctor, whether in your opinion and judgment there has been an increase in the mortality from typhoid fever in St. Louis since the opening of the drainage canal as compared to mortality for the same number of years immediately prior to the opening, such increase being based upon the typhoid mortality per 100,000, or based upon the percentage typhoid mortality.

"A. In my opinion there has been an increase in the typhoid death rate in St. Louis, based upon the mortality per 100,000 population or upon the percentage of typhoid deaths to the total mortality.

"Q. Upon what facts in evidence do you base this opinion?

"A. I base this opinion upon the study of the facts presented from compilations as to the death rates made from the records of the mortuary office and a comparison of the rates for the two periods.

"Q. State, Doctor, whether or not you have examined the testimony introduced in evidence here by respondents showing from the published reports of the Health Commissioner of St.

Louis, the total number of deaths reported from remittent, intermittent, typho-malaria, congestive and simple continued fevers, and state whether or not you have examined the compilations taken from the original record in the office of the mortuary officer of the city board of health and made a comparison as to the total number of deaths so reported by respondent's testimony upon these various and respective diseases now designated as nondescript, and state whether or not upon your examination of these records there has been, in your judgment or opinion, an increase in the typhoid in the city of St. Louis since the opening of the drainage canal?

"A. I have examined the data given in the Health Commissioner's report and also those given in the compilation from the mortuary office referred to and have compared the date, and would state that it is in my opinion, based upon these examinations and comparisons that there has been an increase in the typhoid death rate in St. Louis during the period covered by the four years, 1900 to 1903, inclusive.

"Q. This compilation from the records of the mortuary office of which you speak is the one represented to you as being prepared by Mr. Lochridge, is it not?

"A. That is the compilation which I referred to.

"Q. And Professor Sedgwick—Mr. Lochridge and Professor Sedgwick?

"A. Yes, sir, I understood the compilation was effected by both, and shown me by Mr. Lochridge in particular.

"Q. State, Doctor, whether or not the increase in typhoid fever deaths in the city of St. Louis since the opening of the drainage canal as compared to the same number of years immediately prior thereto has been a decided increase?

"A. I would state that the comparisons which I have made indicate that the increase has been a very considerable one.

"Q. State whether or not an increase in typhoid fever in St. Louis since the opening of the canal is shown to any considerable extent during the winter months?

"A. I would state that the increase has been more noticeable during the winter and spring months than it has during the summer and autumn months.

"Q. Doctor, are you acquainted with what is known as the Widal test?

"A. I am.

"Q. Please state the purpose for which this test is used?

"A. It is used as one of the aids in the diagnosis of typhoid fever.

"Q. Will you state as a physician and sanitary expert what effect, if any, the use of the Widal test may have upon the reports of typhoid fever deaths by physicians?

"A. I think that the use of the Widal test has probably not affected very materially the reports of deaths of typhoid fever. Its influence has been more marked in the matter of correct diagnosis of the milder cases of typhoid fever.

"Q. Doctor, I will ask you to state whether or not it is usual in all large communities and cities for health authorities to issue circulars urging physicians to report cases of deaths of typhoid fever to them?

"A. Boards of health in large cities usually have regulations relating to the reporting of lists of certain diseases and among these typhoid fever is always included, and it is common for the boards of health to issue circulars to physicians calling to their attention the regulations pertaining to the report of such cases.

"Q. What in your opinion is the effect of the issuance of such circulars upon the typhoid fever death statistics of these communities and large cities to which you referred in your last answer?

"A. As the circulars relate to the reporting of cases and not at all to the reporting of deaths, and as deaths are usually reported to some regular office, and in many instances separate from the board of health, I see no reason why there should be any special effects shown in the reporting of deaths from typhoid fever from such circulars, and I have in my experience not seen any occurrence which would lead me to suppose that there was any such general effect.

"Q. Doctor, at what ages do the most of the deaths from typhoid fever occur?

"A. The ages of most susceptibility to the typhoid fever are from fifteen to thirty, though there are many cases between ten and forty, the cases under ten and over forty being less common than in the other decade.

"Q. Is not the disease rare in infants or persons over sixty years of age?

"A. Yes, sir, the disease is comparatively rare at these ages.

"Q. Doctor, I will ask you if in your professional work you have become associated with the cost, the manner of operation and cost of operation of filtration plants?

"A. I have had occasion to consider the cost of operating filtration plants, especially as related to the expert over-sight of their operation, this having come to my attention through my connection with several water companies." (H. E. Smith, Vol. 8, pp. 7717 to 7722, inclusive.)

"Q. Dr. Smith, in reference to your testimony on cross-examination upon the longevity of the typhoid fever bacilli in a running stream, I will get you to state whether or not in your opinion the present state of bacteriology is such as to enable a sanitary expert to fix with accuracy the longevity of a typhoid fever bacillus in a running stream, under all conditions and at all possible times, and to state with even approximate accuracy the comparative resistance of a colon bacillus and the typhoid bacillus in a running stream under all possible conditions and at all possible times or to deduce from any experiments heretofore made and introduced as evidence in this case such true and trustworthy information as would enable you to conclude that a sewage polluted river might be used for drinking and other domestic purposes with absolute safety at all times and in all seasons?

"A. My reply to your question is a repetition of points which I have previously taken up, and I would therefore reply briefly that in my opinion the present state of bacteriology is not such as will permit an expert to fix with accuracy the longevity of the typhoid bacillus in a running stream under all conditions and at all possible times.

"Further, that it is not possible to state with accuracy the comparative resistance of the colon and typhoid bacilli in a running stream under all possible conditions and at all possible times; and further, that it is my opinion the present state of bacteriology is such that it is not possible to conclude from bacteriological analysis that a sewage polluted stream might be so purified as to be used for drinking and other domestic purposes with absolute safety at all times and all seasons.

"Q. What effect has a flood upon the watershed of the DesPlaines river and the upper Illinois river upon the sewage of Chicago coming through the canal during the time of such flood?

"A. The effect of a flood at this point would be first to dilute the sewage and hasten the period of passage of it through the river.

"Q. State, Doctor, whether or not, under such flood conditions as mentioned in the last question, it would prolong the life of the typhoid bacilli and other pathogenic organisms?

"A. The trend, as already stated, of bacteriology researches is to show that concentrated sewage has some deleterious effect upon the life of the typhoid bacilli, consequently the effect of diluting the sewage by floods in the upper Illinois river would be to introduce a condition which would tend to increase the longevity of the typhoid bacilli in the water, first, by the dilution of the sewage itself, and, second, by carrying the organisms quicker into the lower stretches of the river where there is more dilution from natural causes.

"Q. Doctor, assuming that the total area of the Illinois river watershed is 32,081 square miles; that the total area of the Mississippi river watershed above St. Louis, Missouri, exclusive of Illinois, is 1,396,170 square miles; assuming that the total drainage area of the Missouri river is 520,086 square miles; assuming that the total urban population, including the Sanitary District of Chicago, upon the Illinois river is 1,843,800; that the total population upon the Missouri river is 552,000 from the mouth of said river to and including the city of Omaha; that the total population upon the Mississippi from Minneapolis is 697,200; please state your opinion as to which of these rivers would

be the more unsafe and the more liable to contain dangerous disease producing organisms, basing your opinion upon your knowledge as a sanitarian and epidemiologist, and upon all of the chemical and bacteriological data that have been introduced in evidence in this case, and which you have observed, including the tables in Streams Examination, the health reports of the Board of Health of the State of Illinois, and the report of the University of the State of Illinois, and the tables and the experiments in reference to the colon and bacterial counts introduced in evidence by Professor Jordan, aside from those contained in the books just mentioned, including also the tables of results introduced in evidence as to the longevity of the typhoid germ in the parchment and cellodin sacs and the experiment of Doctors Zeit, Jordan and Russell?

"A. I would state that I have considered the data summarized in your question and would state it as my opinion that the water of the Illinois river would be most likely to contain the largest relative number of disease organisms such as are transmitted by sewage.

"Q. Based upon the same assumptions, state whether or not it is your opinion that the Illinois river does or does not contain more disease producing organisms than either of the other two?

"A. In my opinion the waters of the Illinois river do contain relatively more disease germs such as are transmitted by sewage than the waters of the other rivers mentioned.

"Q. State whether or not that opinion applies to the condition of the water in the Illinois river at its mouth, the Mississippi river at a point immediately above Grafton, and the Missouri river at its mouth?

"A. In my opinion this does apply to the water at the mouth of the Illinois river as contrasted to the water at the mouth of the Missouri, in the Mississippi, in the immediate neighborhood at the points referred to." (H. E. Smith, Vol. 8, pp. 7755 to 7760.)

JOHN W. ALVORD testified in part as follows:

"Q. Are you familiar with the results of the experiments found in the reports of the Massachusetts Board of Health in which Hiram T. Mills presents data on the longevity of typhoid bacilli in the waters of the Merrimac river, which results were obtained by him upon analysis and experiments conducted by him?

"A. I am.

"Q. Where, if any, do you find other similar experiments or determinations?

"A. There will be found in the proceedings ofthe Sanitary Institute of 1899 some experiments made by Dr. Horrocks which appear to be similar to those carried out by Mr. Mills. These experiments are also quoted in Mr. Samuel Rideal's book on sewage, on page 70.

"Q. Are the experiments that you are quoting the experiments of Mills?

"A. No sir, Horrocks.

"Q. Are you familiar with the sewerage system of Chicago?

"A. I am. A portion of it has been constructed under my design and supervision.

"Q. Under what conditions in your opinion are typhoid bacilli carried away from Chicago so as to approximate conditions which Mr. Hiram F. Mills and Dr. Horrocks used in their experimental work?

"A. The sewerage system of Chicago has very flat gradients and requires frequent artificial flushing. It has been the history of heavy rainfalls in that city that the entire content of the sewers are at such times disgorged into the river bringing into it a mass of pollution which has been accumulating for months together. Before the opening of the drainage canal such periods were extremely dangerous to the water supply of the city, as was shown in the increase in typhoid deaths following the period of such contamination. Such heavy flushings of rainfall occur ordinarily in the early spring or after the breaking up of the winter and at times when the temperature is most favorable to the longevity of the typhoid germ and greatly increases

for the time being the rate of pollution in the drainage canal and DesPlaines and Illinois rivers.

"In my opinion the action of such a flushing of the Chicago sewer system into the Chicago river with its present large proportion of pure water and low temperature furnishes conditions which parallel or indeed form more favorable conditions to the longevity of pathogenic bacteria than those under which the experimental work above noted were taken. The discharge of this various amount of pollution at times of flood waters appears also to furnish the necessary velocity for rapid conveyance through the drainage canal down the DesPlaines and Illinois rivers to the intake of the St. Louis water supply; the increment of tributary streams also increases the dilution and decreases the chance of toxic destruction of the total number of typhoid germs present. Such conditions are prevalent in greater or less degree during many times of each spring.

"Q. In what you have said of the spring flood, do you have reference to the ordinary spring floods or to the exceptional floods which sometimes occur in this region?

"A. My answer refers entirely to ordinary conditions, such as occur perhaps eight or ten times or more in the spring of each year and often at other times in the year, rather than to exceptional floods such as that of 1888 or 1892 and one or two other heavy floods in which extreme high water marks were reached. Such floods would naturally produce the danger from typhoid pollution to greater distances from the source or origin.

"Q. Are there any other evidences from the testimony introduced in this case and which you have observed which would increase the flow above that mentioned by you?

"A. Yes, sir, in the case of heavy rainfall on the watershed of the Chicago river, it is often necessary, in order to prevent flow into Lake Michigan through the main river, to lower the Bear Trap Dam at Lockport so as to produce greater velocity at all stations down the channel at such times. This undoubtedly aids in the rapidity with which pollution is conveyed away from Chicago down the channel of the DesPlaines and Illinois rivers.

"Q. What are the conditions of stream flow in the Des Plaines river?

"A. Below the outlet of the drainage canal at Lockport, the Des Plaines river flows very rapidly to a pool formed by what is known as dam number one at Joliet. This descent over ordinary and normal flow produces rapid velocity and a slight rise, but rainfall will develop velocity in the channel of from 40 to 60 miles per day." (Alvord's testimony, Vol. 8, pp. 7771 to 7774.)

"Q. What are the conditions of flow in the DesPlaines and Illinois river as far down as the Marseilles dam?

"A. Below dam number one and at Joliet the flow again becomes very rapid at times of moderate rises. This flow is slightly checked through Lake Joliet, but there is a further rapidity incurred on its outlet all the way down the mouth of the Kankakee river. Below this point the Marseilles dam slightly checks the current.

"Q. What are the conditions of flow in the Illinois river immediately below the Marseilles dam, below Marseilles at Peru?

"A. Another rapid flow takes place below the Marseilles dam as far down as to Peru, where the influence of the Henry dam is felt.

"Q. State whether or not that is especially true in time of spring floods or rises?

"A. In the time of spring rises the velocity in these reaches is very materially increased, running, as I have said, up to as high as forty to sixty miles a day.

"Q. Are you familiar with the testimony of Mr. Randolph in this case?

"A. I have read Mr. Randolph's testimony.

"Q. Taking into consideration the testimony of Mr. Randolph and the testimony of all other witnesses affecting the subject of hydraulics and sanitary engineering, I will ask you to state, Mr. Alvord, what effect, if any, has the discharge of 250,000 cubic feet of water per minute through the Chicago Drainage Canal upon the dangerous and deleterious substances

contained in the sewage discharged into the Chicago river and the drainage canal?

"A. The effect is to materially increase the current of the DesPlaines and Illinois river and to carry dangerous pollution to greater distances and with more rapidity." (Alvord, Vol. 8, pp. 7774-5.)

TYPHOID LONGEVITY.

"Q. What do you consider in your practice and in the recommendations which you make in your profession as a fair statement of the longevity of typhoid organisms which would lead you to give what you consider conservative advice upon this subject?

"A. I have for some years past considered the life of the typhoid bacilli would be from sixty to ninety days under favorable environments, and while large masses of such bacilli might be removed from any given source of supply in a comparatively short time under unfavorable environments, it would not be safe to assume that a water once thus polluted would be safe to recommend for public use under the time given, unless the contamination were eliminated by a carefully designed and properly operated system of purification." (Alvord, Vol. 8, 7771-4.)

VELOCITY OF ILLINOIS RIVER.

"Q. Are you familiar with the flow measurements of the Chicago river, the main drainage canal, the Des Plaines river and the Illinois river as described by Mr. Randolph in his testimony?

"A. I have studied them.

"Q. Do you know the discharge of the river at the time these observations were made under Mr. Randolph's directions?

"A. I am unable to find anything in Mr. Randolph's testimony which gives any clue to the amount of discharge in the Des Plaines and Illinois river, either at Joliet or Peoria, and therefore am unable to determine what stage the river was in at the time of his float measurement. The times of these experiments were in July, 1903, as appears by the record, and such

time is not covered by the table of discharge given in his testimony at Lockport, nor are any gauge readings given at Peoria where the testimony includes a rating table. I only find the statement that the floats passed over this distance in fifteen days, which is raised to eighteen and one-half days by dividing by eight-tenths.

"Q. What distance do you refer to in your last answer?

"A. The distance from the Chicago river to the Chain of Rocks in the Mississippi above St. Louis.

"Q. As a hydraulic engineer, state whether or not the time limit as ascertained by the floats should be raised in the manner indicated by Mr. Randolph in his testimony, by dividing by .8?

"A. I fail to see the pertinency of his conclusion that a correction should be made, tending to reduce the maximum surface velocity to the mean velocity of flow. The use of the .8 correction, in the manner described in Mr. Randolph's testimony is a very rough approximation, used by hydraulic engineers when surface floats are run in the most rapid part of the channel of a river to determine the average flow for the whole cross section of the channel in order to get at the quantity passing a given point per second. In the case under consideration, we are not endeavoring to determine the quantity of water passing any given cross section per second, but the problem presented is what length of time will any given pollution, flowing in mid channel, pass over the necessary distance from the Chicago river to the Chain of Rocks. This only requires, in my opinion, a determination of the mean velocity of the bore or central section of the stream.

"Q. Do you as a hydraulic engineer consider the floats described by Mr. Randolph and Mr. Crane as surface floats?

"A. I should not consider them so. As described in the testimony they appear to be partially submerged, and I believe they give the mean velocity of the central portion of the stream with a fair degree of accuracy.

"Q. Assuming, Mr. Alvord, that these determinations, as made by Mr. Randolph, give the mean velocity of the central portion of the stream, state whether or not in your opinion cor-

rections of the character named and described by Mr. Randolph are necessary?

"A. I believe that they are not necessary.

"Q. What, then, would you consider the length of time that it would take pollution to pass over the described distance as the results of these experiments so conducted by Mr. Randolph at the time such experiments were made?

"A. I should judge that fifteen days' actual time would fairly represent the ability of the water of the Illinois and Des Plaines rivers to carry pollution to the Chain of Rocks at the stage when the experiments were made.

"Q. State whether or not in your opinion the mean flow of the stream should be considered as the time element in the passage of sewage and pollution from a given point to a point below on that stream?

"A. I think it should not. Pollution is carried much faster on a given stream than would be indicated by a mean average flow. It may not be carried as fast as the very fastest thread of the stream, but it is certainly carried as fast as the average velocity of the central or fastest part.

"Q. Have you examined the evidence of the experiments conducted by Professor Van Ornum, described in the records of this case?

"A. I have.

"Q. Taking into consideration the testimony of Mr. Randolph in the experiment which he conducted with the floats in obtaining the velocity of the water in the Illinois river, in July, 1903, I will ask you to state what conclusions you draw from a comparison of the respective velocities obtained by Mr. Randolph and Professor Van Ornum, and taking into consideration the evidence as to the gauge readings that existed for a period prior to these experiments and subsequent thereto, as introduced in evidence by Mr. Randolph and Crane, in what way do these experiments represent the minimum or maximum velocity of the water in the Illinois river?

"A. I should judge, in answer to the first part of your question, that the float experiments of Mr. Randolph in July, 1903, were undertaken at a very much lower stage of the river

than were those of Professor Van Ornum in March, 1903, as Professor Van Ornum finds materially greater velocity than does Mr. Randolph.

"I also observe that Professor Van Ornum commenced his float experiments in a low stage point, between two March rises in the river. There were flowing over the Bear Trap Dam at the time he commenced his operations, as taken from the figures in the tables in the evidence, 289,000 cubic feet per minute, which gives a rather low velocity in the drainage channel. About 394,000 cubic feet per minute was passing over dam number one at Joliet at the same time.

"Eight days prior to this, and on the 8th and 9th of March, 707,000 and 718,000 cubic feet per minute, respectively, passed over the dam at Joliet.

"Five days after Professor Van Ornum commenced his experiments, or on the 21st and 22nd of March, 764,000 and 711,000 cubic feet per minute passed over dam number one, or nearly double the amount of flow, both earlier and later, was in existence than occurred when his experiments were commenced.

"It would seem, therefore, that Professor Van Ornum's experiments were undertaken at a very comparatively high stage but not by any means the highest stage so far as the drainage channel and the upper portion of the Des Plaines river are concerned.

"In passing Peoria, Professor Van Ornum observes the stage of water upon the gauge, which I find, by referring to the table of flow submitted by Mr. Jacob A. Harmon, in this case, gives a flow of about 50,000 cubic feet per second. This flow would correspond to a stage of the river which is somewhat overflowing the banks in the lower courses.

"As Professor Van Ornum used submerged floats, I feel that the actual time traveled by the velocity floats represents fairly the mean velocity of the pollution vehicle, and I take the total time as represented by these floats as representing the total time which it requires to travel the total distance under consideration, with the exception that I believe that there are times when the velocity in the drainage channel in that portion of

the river immediately below the Bear Trap Dam is greater than those which he found.

"In 1898 I was engaged as consulting engineer for the State Board of Canal Commissioners in litigation with the Sanitary District of Chicago over certain water powers, and these channels below the Bear Trap Dam, and had occasion to very carefully study the velocities and stages and various stages in this vicinity. I have, therefore, verified Professor Van Ornum's float experiments in this vicinity, recognizing them to correspond with what I know to be the facts in the spring rises in the upper portion of the course under consideration. Below Lake Joliet I have accepted Professor Van Ornum's experiments to the Chain of Rocks as being properly indicative of what might happen in ordinary spring floods.

"From Bridgeport to the Chain of Rocks I find that 9.8 days is consumed, using mean velocity to Joliet, and Professor Van Ornum's float experiments from there to the Chain of Rocks. I do not consider that this is the shortest time in which pollution would travel this distance, but believe, that the maximum flood, such as occurred in 1892, would adduce this time to at least eight days and possibly slightly less. The 9.8 days represents to my mind a stage which could be counted upon as occurring a number of times in each year.

"Q. State whether or not you have had occasion to examine and study the velocity and stages of the rivers in question, in the course of your professional career?

"A. I have.

"Q. From what you have said of your observations of the testimony introduced in this case and of the testimony of Mr. Randolph, from his float experiments, state whether or not in your opinion the float experiments of Mr. Randolph represent a minimum velocity of the water in the Illinois river from Chicago to St. Louis at all times of the year?

"A. Not having been able to ascertain the specific stage at the time of Mr. Randolph's experiments, I should be unable to state positively that his experiment was made at the minimum stage of the river, but speaking generally it is my impression

that it was and represents the average of the minimum velocity in the ordinary dry seasons of the year between the Chicago river and the Chain of Rocks." (Alvord's testimony, Vol. 8, pages 7775 to 7780, inclusive.)

SEPTIC ACTION.

"Q. State whether or not you have given attention to the development of processes of sewage purification by means of septic tanks?

"A. I have given particular attention to the development of septic tanks and have designed some ten or fifteen plants for municipalities in which a septic tank has been employed on my recommendations. Of these plants eight septic tanks have been constructed under my immediate supervision for different municipalities and have been in operation for periods ranging from one to four years. Two of these plants have been under my immediate supervision ever since construction, and I have watched the operation of others.

"Q. What is septic action and how long should sewage remain in a septic tank in order to obtain practical results from a sanitary standpoint?

"A. Septic action is the profess of breaking down the organic matters in sewage by micro-organisms or their products in the absence of oxygen. This process is continuously brought about by allowing the sewage to come nearly or quite, to a state of rest in deep tanks and allowing it to remain so until the dissolved oxygen present, if any, is exhausted and until the solid particles of the sewage have been attacked and broken up more or less in soluble compounds. It is desirable in order to provide favorable conditions for this process that the temperature remain as constant as possible and very high, and it is preferable that light and air should be excluded, although this is not absolutely essential. The proper period of rest necessary to get the best results will vary with the composition of the sewage, its temperature and character. It has been found desirable to adjust the rest period so that the temperature and other variables can be controlled and the period of rest adapted

to the concentration of the sewage and its relative flow proportioned to the tank in which it is confined.

"Q. State whether or not flowing sewage ordinarily undergoes the process of septic action?

"A. It does not ordinarily.

"Q. State whether or not diluted sewage flowing in open channels simulate septic tank conditions?

"A. It would not. The flow of liquids through open channels tend to bring all portions of the liquid from time to time to the surface, where it may receive oxidizing influences tending to retard septic action.

"Q. Are you acquainted with the present physical condition of the Chicago Drainage Canal?

"A. I am.

"Q. Please compare the conditions existing in the Chicago Drainage Canal with those of a true septic tank?

"A. In the Chicago Drainage Canal we have a large volume of diluted sewage flowing at the rate of one to three feet per second, giving ample opportunity for renewing its dissolved oxygen. And we have this action further increased by the opportunity of the wind to stir the surface of the stream and still further oxygenate it.

"We have also an opportunity for exposure to low temperatures, light, etc., which are detrimental to the septic action.

"Q. State whether or not septic action to any considerable extent takes place in the sewage of Chicago during its passage through the drainage canal?

"A. It does not.

"Q. Are you acquainted with the chemical data that has been introduced in evidence by the defendants?

"A. I am to some extent.

"Q. State whether or not in your opinion the chemical data introduced by the defendants with reference to the character of the contents of the Chicago Drainage Canal, indicate any septic action has taken place?

"A. My opinion is that they do not. The amount of improvement in the sewage in its travel of the drainage canal found by Professor Kinnicutt in his testimony in this case would

seem to me to be largely due to aerobic action. Possibly there is anaerobic action to a very limited extent, but not enough in my opinion, to influence the results perceptibly.

"Q. State whether or not the extensive dilution of the sewage of the city of Chicago by the richly oxygenated water of Lake Michigan, is a useful preliminary to septic action?

"A. It is not. On the contrary it is distinctly opposed to the inception of septic action. In good practice, in the designing of septic tanks, it is the endeavor always to bring the sewage into the tank as quietly as possible, undiluted with surface or underground waters containing undissolved oxygen.

"Q. State whether or not you were familiar with the South Branch of the Chicago river prior to the opening of the drainage canal?

"A. I am.

"Q. What was the condition of that part of the river at that time?

"A. It presented all the characteristics of septic action to a marked degree.

"Q. What were those characteristics?

"A. The absence of marked current, and the presence in certain places of more foul products and considerable surface scum, the absence of undissolved oxygen as shown by chemical examinations and the visible production of gases bubbling up from the depths below, such as characterize the septic tank when in active reduction of its organic matter.

"Q. State whether or not in your opinion, typhoid germs are now more able to survive longer under the present condition of sewage dilution in the drainage canal than they could formerly have survived in the South Branch of the Chicago river or in the Illinois and Michigan Canal?

"A. I believe that typhoid germs can survive materially longer under the present conditions than was the case formerly in the Illinois and Michigan Canal, and the South Branch of the Chicago river." (Alvord, Vol. 8, pp. 7787-7791.)

CHICAGO SEWAGE CAN BE TREATED.

"Q. Mr. Hering, who testified for the defendants on March 10th last, was asked by counsel for the defendants the following question: 'From what you know of the question of disposal of sewage and from the knowledge which you have in regard to the drainage canal, the manner in which it is operated, and taking into consideration the experience you have had since you made your preliminary report, what changes would you recommend for the sewage disposal of the city of Chicago if the same problem was submitted to you now which was submitted to you in 1886, as a sanitary and hydraulic engineer?' Answering this question, Mr. Hering said that in considering the several ways of disposing of the sewage of Chicago, from personal knowledge and experience, my recommendation would be that the sewage of Chicago should be disposed of by dilution through the channel substantially as that which has been constructed with the subsequent discharge into the DesPlaines and Illinois rivers.' Thereupon the following further question was asked him: 'In the study of this problem have you discovered anything that would change the view expressed by you in your preliminary report at that time?' In answer to which question Mr. Hering said: 'I have not.' I will ask you, Mr. Alvord, to state whether or not there are in your opinion, any practical modifications of the existing system of sewage disposal of the city of Chicago by which the drainage canal could still be employed for keeping the Chicago river in an inoffensive condition and yet avoid the pouring of unpurified sewage into and through the canal over the Bear Trap Dam at Lockport and into the DesPlaines and Illinois rivers?

"A. I am of the opinion that it is entirely practicable to retain the drainage channel so that it can be still employed for keeping the Chicago river in condition and yet avoid pouring unpurified sewage into and through the canal and into the DesPlaines and Illinois rivers, and I would suggest as the proper remedy the construction of suitable intercepting sewers along the Chicago river and its branches, by means of which the sew-

age flow of the city may be kept out of the Chicago river and lead along its banks to the upper end of the drainage channel beyond Bridgeport and then raised by a suitable pumping station, preferably operated with water power derived from the drainage canal to and into a suitable purification plant constructed in accordance with the latest bacteriological principles and effectually remove from such sewage all or practically all of its organic wastes and pathogenic bacteria, and emptying the effluent from such sewage plant into the drainage channel near Bridgeport, to be conveyed through the same and through the DesPlaines and the Illinois rivers in a harmless and purified state.

"Q. State whether or not you have considered the relative expense of such a plant as you have described in your last answer?

"A. I have considered the expense in a general way, and am of the opinion that such intercepting sewers and purification plant could be constructed at an expense no greater than that necessary to widen the South Branch of the Chicago river in order to increase its flow of dilution water to the requirements of dilution.

"And I am further of the opinion that the operating expense of such a plant would be no greater than the operating expense of the present system of pumping sewage and the necessary dilution water through the same for the northerly and southerly portions of the sanitary district and the dilution water for the proposed additions to such sanitary district." (Alvord, 8, pages 7794 to 7796.)

PROF. W. T. SEDGWICK, testified in rebuttal, in part, as follows:

BASIS OF SHOWING TYPHOID MORTALITY.

"Q. Professor, I will ask you to explain why you have used in your testimony in this case the percentage mortality basis in determining the increase or decrease of typhoid fever death rate in the city of St. Louis?

"A. I think I stated briefly when testifying in chief my reasons for using the percentage mortality basis, but in as much as witnesses for the defendants have critized this method, I desire to state further my reasons and to show by two simple charts (Charts on pages 7957-7958) that in the case of two cities of closely similar population, St. Louis and Boston, this method yields results similar to those which would be obtained by the deaths per 100,000 basis, that is, the basis of deaths to population. Both methods are in common use, and it is to a considerable extent a matter of choice or taste whether one shall employ one method or the other. In favor of the percentage mortality method is the fact that it eliminates from the problem altogether the question of population, and inasmuch as population in many communities, especially between census years, is a most uncertain matter, I personally make frequent use of the percentage mortality method.

"On the other hand, there is no doubt that under certain circumstances the other method furnishes more instructive and sometimes more accurate results. This is particularly true when the population is accurately known.

"In order, however, to show that in the present case the method of percentage mortality, that is to say, the proportion of the typhoid deaths to the total number of deaths is neither inaccurate nor misleading. I have prepared the charts above referred to. One of these, entitled 'Typhoid percentage to total mortality,' is constructed upon the basis which I employed in my testimony in chief and upon this chart I have indicated not only the typhoid fever death rate computed in this way for the city of St. Louis, but also for that of Boston, a city of almost exactly the same size.

"The second chart, entitled 'Typhoid death per 100,000 Population,' is constructed upon the other plan and represents the deaths from typhoid fever in St. Louis and in Boston for the same years covered by the first diagram, namely ten years, 1884 to 1894. These charts show, I think, clearly the fact that no misleading conclusion could have been drawn from my ori-

ginal testimony, for both demonstrate clearly and to the same effect the essentian fact as testified to at that time." (See Sedgwick's testimony, Vol. 8, pages 7955-6-7 and 8.)

NO RIVER IN GREAT BRITAIN LONG ENOUGH FOR SELF-PURIFICATION TO TAKE PLACE.

"Q. In the testimony of defendants, taken on February 3rd, 1904, Professor Jordan was asked the following question: 'Professor Sedgwick states * * * the River Commissioners of Great Britain, in a report published by them in 1874, stated that there is no river in England long enough to purify itself from any sewage admitted to it even at its source. That stands as one of the axioms of sanitary science today, that those River Commissioners, in 1874, I think it was, made the statement that there is no river in the United Kingdom, I think they said, long enough to purify itself of any sewage introduced into it, introduced at its source and of course some of the rivers of the United Kingdom are very long.' Professor Jordan stated that he was not able to find this quotation, saying that the closest that he could find to it was the following: 'It will be safe to infer that from the above results there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation.' Professor Jordan was further asked, 'What is the difference between the expression 'to effect the destruction of sewage by oxidation,' and the expression 'to purify itself of any sewage introduced into it at its source.''

"Now, Professor Sedgwick, I will ask you to state whether or not the quotation as you gave it from memory or the version suggested by Professor Jordan is the nearer the true quotation and was essentially correct?

"A. I think that the quotation which I made from memory was nearer the original, which I will now read from the report referred to by myself, and I presume by Professor Jordan, namely the Sixth Report of the Rivers Pollution Commission appointed in 1868, which inquired into the best means of pre-

venting the pollution of rivers. This report was published in London in 1874 as one of the British Blue Books, and on page 427 occurs the statement to which I referred, as follows:

"There is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it, even at its source."

"I may say that I am not surprised that Professor Jordan had difficulty in discovering this precise quotation, inasmuch as the book is a large one and is not at all well arranged. I may say further that the popular version of the statement made by the Commissioners is simply that 'There is no river in England long enough to purify itself.' It is easy to see how this shorter version has arisen, and if it were simply made to run 'There is no river in the United Kingdom long enough to purify itself,' I believe that it would substantially represent the true doctrine of sanitary science today." (Sedgwick, Vol. 8, pp. 7959.7960.)

LIFE OF TYPHOID IN DRAINAGE CANAL.

"Q. Professor Sedgwick, have you examined the testimony of Professor Jordan, Dr. Zeit and Professor Russell, concerning their experiments upon the longevity of the typhoid germs in parchment and cellodin sacs and agar blocks suspended in Lake Michigan, the Chicago river, the Drainage Canal and the Illinois river, and all other similar experiments made by these gentlemen and introduced in evidence?

"A. I have.

"Q. State whether or not you are able from the determinations made by them in the above connection to formulate an opinion as to the longevity of typhoid organisms contained in these waters?

"A. No, I should not be able either to form or to formulate a comprehensive opinion from these experiments alone. It is clear, of course, that, as shown in these experiments, the germs survive for certain lengths of time, but I should be unable to conclude from the experiments that under different conditions typhoid fever germs might not survive for longer times. The experiments appear to me to have been very ingenious and interesting, but not by any means conclusive upon

the whole subject of the longevity of typhoid fever germs in moving bodies of sewage or water.

"Q. State whether or not in your opinion these experiments just referred to simulate natural conditions in the water?

"A. Undoubtedly they were devised as far as possible to do this, but in a great deal of experimental work the result of the experimenter falls short of his endeavors. I do not see how it is possible in the present state of bacteriology to devise any series of experiments which shall accurately and completely imitate the infinitely various conditions of running streams, and particularly streams such as the Chicago river, the Chicago Drainage Canal and the Illinois river, subject as these are, to an endless variety of alterations, in their physical, chemical and bacteriological conditions.

"For example, these experiments were carried on in cold weather I believe, but even if they had been carried on for an entire year, under all actual variations and conditions, they would still, in my judgment, have been incomplete, for the reason that in other years under other conditions, organisms as sensitive as typhoid fever microbes are, might have encountered environments which would have materially altered the results. Besides, it seems to me that the conclusions arrived at by these able investigators indicate a shortness of life of the typhoid fever germs, which is not in harmony with the longevity naturally deducible from the experience of mankind with epidemics due to typhoid infected waters, and while evidence of this kind is hard to reduce to a strictly scientific basis, it has, I believe, nevertheless great value, for the reason that it is the outcome of the experience of the race.

"Furthermore, the results of these experiments, broadly speaking, indicate a considerably shorter period of life for the typhoid fever germs in sewage and water than has been found by the mapority of previous investigators. My own opinion is that a greater number of experiments, conducted for a longer time, and under different conditions, would not fail to show that typhoid fever germs may, and do, live in sewage and running streams a very much longer time than was found in these particular experiments.

"Q. In what particular way did these experiments fail to represent true natural conditions?

"A. I should not say that these experiments failed to represent natural conditions, any further than many experiments must necessarily fail to imitate natural conditions. I mean by that, that these experiments were undoubtedly well planned and well conducted, but it is easy to suggest a great number of points in which they do nevertheless fail, the principal failure being to duplicate all the various conditions of the running stream. Some other matters have already been mentioned by witnesses for complainant in rebuttal, such, for example, as the fact that the germs in the several experiments were anchored, so to speak, at fixed points, instead of being allowed to float down the stream with a particular body of water. Anyone can readily see that this is an unnatural condition, especially in the case of the Drainage Canal, and the Chicago and Illinois rivers, for the reason that the chemical composition of these bodies of sewage and water is subject to frequent changes. If, for example, the waste from a large industrial establishment should be turned into the Chicago river at any particular moment, the water which received it would vary materially in chemical composition from the water just preceding and just following it. For this reason sacks or blocks at anchor are probably exposed to a greater variety of changes than they would be exposed to if they were to float down the stream with one particular body of water.

The sewage discharged from a city at night is a very different body, chemically, from that discharged by day. The sewage discharged during a heavy storm is very different from that discharged in dry weather. Again, the seasonal conditions must be taken into account, and in the case of the Illinois river physical conditions, such as floods in the tributaries, or the overflow of lakes upon these tributaries, bringing in new materials and a strange bacterial flora. These and many other things which I need not, and could not mention, undoubtedly play a highly important part. The trouble is that in trying to fix the longevity of typhoid fever or any other microbes we are dealing with extremely sensitive and almost infinitesimal organisms which

we have only within the last few years learned to recognize at all, and have not yet by any means learned to know thoroughly. I believe, therefore, that while the experiments of the experts for the defense are interesting, ingenious and important in the science of bacteriology, they should not be allowed to have too much weight in determining the issues in this case.

"Q. Assuming, Professor, that the longevity of a typhoid fever germ in an open sewer, such as the Drainage Canal, as characterized by different witnesses, and as limited by the experiments of Doctors Zeit, Jordan and Russell to from two to four days, in what respect is the credibility of these experiments reflected upon by the ordinary, usual and general practice of sanitarians in the construction and recommendations for the construction of plants for the treatment of water for domestic purposes, which has been subjected to sewage pollution?

"A. As I understand the question, it is my opinion that their results are so far out of harmony with the results of previous investigators and so contrary to the prevailing opinion upon this subject which forms the basis of the practice of sanitarians and engineers in forming their opinions concerning the availability of polluted streams for drinking and other domestic purposes, as to throw grave doubt upon the results, and therefore upon the conclusions to which these naturally lead." (Sedgwick, Vol. 8, pp. 7960-7963.)

TYPHOID IN ST. LOUIS DUE IN PART FROM CHICAGO SEWAGE.

"Q. Professor, have you examined the testimony of Professor Mason with reference to the effect that increased typhoid fever in the city of Chicago would have upon typhoid conditions in the city of St. Louis, assuming that the germs of this disease pass from Chicago to St. Louis?

"A. I have.

"Q. State whether or not, based upon the chemical and bacterial analyses that have been introduced in evidence in this case on the part of the respondent, and upon the physical conditions and surroundings of the Illinois river, including the

sanitary district of Chicago, what effect would you reasonably expect an increase in typhoid in Chicago to have upon typhoid conditions in St. Louis?

"A. Taking into consideration the distance between the two cities and the time required for the passage of typhoid fever germs from Chicago to St. Louis down the Drainage Canal, the DesPlaines, Illinois and Mississippi rivers, and taking into consideration also the character of the Drainage Canal and of the Illinois river, and considering also the fact that the water drawn from the intake at the chain of rocks by the city of St. Louis for its public supply is now, and long has been, subjected to extensive sedimentation, I should not expect to find any close correspondence between the details of the typhoid fever curves of the cities of Chicago and St. Louis over such periods.

"We must also take into consideration the fact referred to by Professor Zeit in his testimony, that typhoid germs arriving at the city of St. Louis might act through the formation of local foci of infection, the time required for which must always be of uncertain duration.

"I should therefore expect to find a correspondence between the prevalence of the diseases in the two cities, in general and broadly speaking, only when considerable periods were dealt with. It is, of course, probable that a very severe epidemic of typhoid fever in Chicago would make itself felt in St. Louis in such a way that cause and effect could be clearly connected, but here again much would depend upon the season of the year, the rate of flow in the Illinois and Mississippi rivers, the local conditions of the sewage, and the efficiency of sedimentation in the sedimentation basins of the water works of St. Louis. I am therefore not surprised to find that the curves of Professor Mason do not indicate any conspicuous and constant relation between waves of typhoid fever in Chicago and similar waves in St. Louis. I do believe, however, that by taking long periods and averages we ought to see and do see a definite connection, as for example, when comparing typhoid fever in the years following 1900, with those preceding that date." (Sedgwick, Vol. 8, pp. 7963-7964.)

TESTS ON BACILLI COLI COMMUNIS.

"Q. State whether or not you have examined the evidence of Professor Jordan and Professor Burrill upon the colon tests made by them and their evidence in connection therewith?

"A. I have.

"Q. State, Professor, from the consideration of these colon tests and tables so introduced by Professors Jordan and Burrill, together with the other testimony upon the chemical and bacterial data, your conclusions as to the appearance of pathogenic bacteria in the waters of the Illinois river at its mouth, originating at Chicago?

"A. The tests applied by Professor Jordan and Professor Burrill to the water of the Illinois river, while they show a very great decline in the numbers of these organisms present in the lower reaches of the river at the times when the specimens examined were taken, in those particular specimens, do not, in my opinion, enable any one to form an accurate opinion as to the presence or absence of typhoid fever germs in the waters of that river at those points.

The reasons for my opinion are, first, that only a comparatively small number of specimens was examined, and from the nature of the case such specimens only imperfectly represent the true and complete character of the streams at all times and all seasons, and, second, that while the colon test is a valuable aid in sanitary water analysis, it is by no means a sure and perfect measure of the presence or absence either of the bacillus coli itself or of the typhoid fever bacillus. It is not a sure and perfect test for the colon bacillus at all times, because experiments have shown that this organism sometimes fails to make its appearance in the tests applied, even where it is proven to be present by a further study of the same specimen. And it is by no means a sure test of the presence or absence of the typhoid fever germ, not only for that reason, but also because it is not yet established beyond all reasonable doubt that the life of the typhoid fever germ so closely resembles that of the colon bacil-

lus as to be fairly represented by it under all conditions at all times and all seasons.

"I am therefore of the opinion that while the experiments of Professors Jordan and Burrill throw great light upon the process of bacterial purification going on in the Illinois river, they do not by any means establish the fact that typhoid fever is completely or effectually removed from the waters of that river before it empties into the Mississippi at Grafton." (Sedgwick, Vol. 8, pp. 7965-6)

TYPHOID INCREASE IN ST. LOUIS.

"Q. State whether or not you have examined the tables and charts introduced in evidence by Mr. Lochridge, based upon the mortality record of typhoid, typho-malarial, intermittent, remittent, congestive and continued fevers and enteric and bilious fevers?

"A. I have, and I am thoroughly familar with them, for the reason that Mr. Lochridge has frequently consulted me with reference to them, and their preparation, which was begun and carried out by him at my request, and with my constant advice and supervision.

"Q. Will you examine those charts and tables and state what they show with reference to an increase or decrease in typhoid fever since January, 1900, to December, 1903, inclusive, as compared to a corresponding period immediately preceding, and taking into consideration in this connection the deaths reported from malaria, intermittent, remittent, typho-malarial, congestive and continued fevers?

"A. The typhoid fever deaths taken by themselves and alone show a marked annual increase during the last four years; that is to say since the opening of the Chicago Drainange Canal. This increase, moreover, is not only considerable from year to year during this period, but it is much more marked than it was during the preceding period. In fact, during the four years, 1896 to 1899, inclusive, typhoid fever in the city of St. Louis may be said to have been stationary or very nearly so,

and not at all excessive, the annual death rate from typhoid fever measured either by percentage mortality or by comparison with the total population having been such as, broadly speaking, prevails only in cities having good water supplies. But during the last four years of the period under consideration, typhoid fever in St. Louis has risen far above this level, until it stands at the end of the period higher than at any time during the whole period under consideration.

"The testimony introduced by the defendants having tended to show a possibliity of the transfer of deaths from other diseases, especially remittent, intermittent, typho-malaria, conjestive and simple continued fevers into the typhoid group, especially in the latter years under consideration, I have examined with special interest Mr. Lochridge's analysis of these several nondescript fevers, or rather of the deaths attributed to them, and tabulated by him upon his charts; for it was a possibility that some such transfer might in fact have been made. The unquestioned improvement in medical education which has been going on for the last twenty years, especially after the introduction of the Widal test, might conceivable have had some influence in causing such transfer, the effect of which would have been to increase the number of deaths attributed to typhoid fever in the latter years of the period under consideration. Any such change must, however, of necessity, have been gradual, while in point of fact the increase of typhoid fever in the city of St. Louis was sudden, sharp and has thus far been continuous. In the second place the Widal test, having been introduced by the Board of Health of the city of St. Louis early in the year 1897 should have made its influence felt, if it had any in the direction indicated, previous to the year 1900, but no such influence is visible in the figures compiled by Mr. Lochridge or upon his charts. It is not, however, by any means clear that the Widal test would always tend to increase the total deaths from typhoid fever for, while it unquestionably clears up the diagnosis, and in some cases, perhaps, leads to the recording of deaths as due to typhoid fever which with its use might have been referred to some other disease. The Widal test works also in the opposite direction, giving negative results in many suspected

cases and removing from the typhoid group deaths which without its use might have appeared there. It is important to note that only from five to ten per cent of the specimens sent in by physicians for the Widal test ordinarily prove positive, and it is particularly important to note that in the city of St. Louis a large number of cases diagnosed as remittent fever, malaria and typho-malaria fever, the blood from which was subjected to the Widal test, failed to give any typhoid reaction.

"Again, Mr. Lochridge's compilations and charts throw great light upon the whole matter by enabling us to consider the ages of the decedents from the various diseases referred to, as well as the seasons in which they died; and a careful comparison of the incidence of death at the different ages and months, enables one to show beyond doubt that, even if a considerable proportion of the deaths from remittent, congestive and intermittent fevers which occurred previous to the year 1900 were by better diagnosis removed from those groups in the remaining years, these were not in point of fact transferred to the typhoid group.

As to the matter of season it is important to observe in the first place that Mr. Lochridge's charts indicate a considerable increase in typhoid fever in the city since January 1, 1900, at all seasons, but especially that this increase has been greater in the winter and the spring, than it has in the summer. This is one of the most important facts which I deduce from the charts, for it shows in the first place, that the increased number of deaths found in the typhoid group is almost certainly, as proved by this test alone, not due to a transfer of malarial deaths to the typhoid column since malaria is not prevalent in the winter. In the second place, this winter increase is extremely important, for the reason that during the winter months the Missouri river is a less important factor in the water supply of St. Louis than it is during the summer months; so that this winter increase must have had its origin eleswhere than in the Missouri river. I do not think it necessary for me to dwell longer upon these charts which Mr. Lochridge has already explained in detail, and I believe that I have stated some of the principal conclusions to be drawn from them. I will, however, say before leaving them,

that they appear to me to prove beyond all reasonable doubt that the typhoid fever increase in the city of St. Louis since January 1, 1900, has not been due to any transfer of deaths from remittent, intermittent, congestive, typhoid-malaria, or simple continued fevers into the typhoid fever group.

"One thing more I ought to mention. Mr. Lochridge has made a correction indicated by dotted lines upon some of the charts for the localized epidemic of typhoid fever which occurred in November and December, 1899, and the deaths from which continued, apparently into 1900. This epidemic, as I have taken pains to inform myself by inquiry of physicians in different parts of the city and otherwise, was localized in the west central portion of the city, was such that in my judgment could not have been due to a general pollution of the public water supply. I believe that it was due to milk, but I am unable to state this positively.

"Q. In answer to your last question, the last question of mine, did you take into consideration also the age of the patients dying?

"A. I believe that I briefly referred to that matter which is of special importance as establishing some of the facts and conclusions which I mentioned, in the deaths recorded as due to some of the fevers not typhoid. A comparison of the ages of decedents from these diseases and of those from typhoid fever makes it perfectly clear that is, as sometimes happens, the number of deaths from a disease in the first group has declined, this can not be because deaths from this particular disease have been transferred to the typhoid fever group, for the reason that no deaths of corresponding ages can be found in that group.

"Q. State whether or not, professor, from these charts and tables introduced in evidence by Mr. Lochridge, which are based upon the typhoid fever deaths and deaths from the nondescript fevers show in any way an increase of any character since the opening of the Drainage Canal which may be due to the influx of people on account of the construction of the Louisiana Purchase Exposition?

"A. Replying to this question I may say that I have given in the past some attention to the influence which expositions of this kind have upon typhoid fever death rates, for the reason that in the year 1892 I studied the typhoid epidemic in Chicago, as I have already testified in this case. That date was just before the opening of the World's Columbian Exposition, and it was frequently alleged that the excess of typhoid fever in Chicago at that time was due to the influx of workmen and others preparing for that exposition. In studying this question I also examined the typhoid fever mortality of Philadelphia before, during and after the Centennial Exposition of 1876, and found that, while typhoid fever was excessive in Philadelphia during the year of the exposition, it was not much, if any, higher than usual during the years immediately preceding it. Further investigation led me to conclude that the excess of typhoid fever in Chicago just before the opening of that exposition was not due to any influx of outsiders, but to a grossly contaminated water supply, and this latter opinion has come to be generally accepted as true. In fact, during the exposition itself the typhoid fever in the city of Chicago was decidedly lower than it had been in the preceding year, owing to the energetic measures taken by the exposition and city authorities for improving the public water supply. In view of these facts I am of the opinion that no important portion of the increase in typhoid fever in the city of St. Louis since January 1, 1900, can reasonably be attributed to the influx of workmen or others connected with the World's Fair.

"Q. From the examination which you have made of the charts introduced by Mr. Lochridge, and from your general information upon the subject, epidemiologically and otherwise, state what effect in your opinion circular letters sent out by the health department from year to year has had upon the mortality records of the city of St. Louis and especially with reference to typhoid conditions?

"A. I have had much experience with boards of health and their workings, and in many cities I have had occasion to observe that circulars of this kind, issued by boards of health are generally ignored altogether. I am of the opinion that no cir-

culars issued by any board of health and urging the reporting of *cases* of typhoid fever could have any influence upon the reporting of *deaths* from that disease, for the reason that physicians are legally bound to report deaths any how, before a burial permit can be obtained from the board of health or other municipal authority. Such circulars, in fact, sometimes tend to diminish the number of deaths reported from typhoid fever rather than to increase them. I have, indeed, known of a few instances in which a physician had reported a death really due to typhoid fever as due to some other disease because, having failed to report it while living as a case of infectious disease, as required, he feared to incur the displeasure of the authorities if he should report it as a death from that disease, and thus possibly subject himself to a summons, a fine, or other penalty."

(Sedgwick, Vol. 8, pp. 7966-7970.)

SAPROPHYTIC INFLUENCE ON PATHOGENIC BACTERIA.

"Q. Professor, Dr. Zeit, in his testimony along with other witnesses for the defendant attributed extensive destructive effects upon typhoid fever germs in sewage and sewage polluted water to the toxic products of the saprophyte in sewage. State whether or not bacteriologists and epidemiologists agree with him as to these facts?

"A. Unquestionably some would agree with him. Others, like myself, do not accept this view, and against Dr. Zeit's theory I may quote the following experiment made by myself and one of my students, Mr. D. D. Jackson, as long ago as 1893. In this experiment we undertook to test the very point under consideration. A portion of sewage was carefully freed, by filtration, from all microbes present, whether saphrophytic or parasitic. The filtrate was proved to be free from such germs, but was otherwise ordinary sewage, that is to say it contained the toxic products, if any, of the saprophytics which it contained in abundance, and which had been removed by filtration. A portion of this filtered sewage was then seeded with typhoid fever microbes,

to the number of 329 per cc. Now if the toxic products of saprophytes had been capable of destroying typhoid fever germs these should have gradually declined in number. The facts were, however, that one hour later the number present was 333 per cc.; 24 hours later, 63,198, and two days later the typhoid fever germs present were innumerable. This specimen was kept at blood heat. The germs were carefully examined to make certain that they were true typhoid fever bacilli, and were found to be such. The culture was next placed in the ice chest and six days later the number of typhoid fever germs present had fallen to 888,000 per cc.; 12 days after seeding the number present was 832,100 per cc.; 20 days after seeding the number present was 375,000, and 36 days afterwards, 56,500. This experiment satisfied me that whether or not typhoid fever germs ultimately disappear in sewage they are not readily destroyed by the toxic proudcts of saprophytes, but rather multiply and live long in their presence.

"More recently a similar experiment has been made by Dr. W. H. Horrocks, a well known English bacteriologist, in which Dr. Horrocks found abundant typhoid fever germs in sewage, filtered in the same way, after 42 days."

(Sedgwick, Vol. 8, p. 7972.)

SEWAGE FROM CHICAGO HAS AN INJURIOUS EFFECT ON ST. LOUIS.

Q. Professor, you have examined the tables introduced in evidence in this case, contained in the book known as Streams Examination?

A. I have.

Q. You have examined the tables and charts contained in the Illinois State Board of Health Report in troduced in evidence by Professor Long?

A. I have.

Q. State whether or not you have examined the tables introduced in evidence by Professor Palmer aside from those made up by him and contained in Streams Examination?

A. Yes, sir; I have.

Q. Have you examined the tables and bacterial and chemical data of Professors Jourdan and Zeit upon the various chemical and bacterial determinations of the water in the Illinois river and the sanitary canal not contained in Streams Examination?

A. I have; yes, sir.

Q. Taking into consideration, professor, all of the chemical and bacterial data introduced in evidence by the respondents, state whether or not the data so introduced leads you in any way to change your former opinion expressed in this case?

A. I have obtained from these tables and other data a much better knowledge of the process of chemical and bacterial purification going on at certain times and seasons in the Illinois river, but I have failed to discover any reason for changing the opinion which I expressed on my examination in chief a year ago, namely, that the principal part of the increase of typhoid fever in the city of St. Louis, since the first of January, 1900, has been due to the presence of deleterious elements contained in the public water supply, and derived from the unpurified sewage of the city of Chicago. The additional information which I have gained on the history of typhoid fever and other fevers in St. Louis, especially during the last year, has only served to strengthen that opinion."

(Sedgwick, Vol. 8, pp. 7972-3.)

CONDITIONS AS OBSERVED BY PROMINENT LOCAL PHYSICIANS, HOUSE FILTERS HAVE INCREASED IN USE AND PRACTICE OF BOILING THE WATER LARGELY ADVISED. YET TYPHOID DEATHS AND CASES INCREASED.

Since the use of the Widal test in St. Louis, about eight years ago, this favorable effect has been shown upon the typhoid death rate in St. Louis, for the reason that if the diagnosis test be made in the earlier stages of the disease, more intelligent treatment can be administered.

The result of this test has been such that a large number of physicians have been enabled to make a definite report as to the causation of death, and therefore a number of deaths have been attributed to other than typhoid, when, prior to the use of the Widal test, they would have been reported as produced by typhoid.

(See Dr. Goodman's testimony, Vol. 8, p. 7660; Dr. Fischel's testimony, Vol. 8, pp. 7612-14; Dr. Bremer's testimony, Vol. 8, p. 7626; Dr. Saunders' testimony, Vol. 8, p. 7859.)

According to the testimony of the local physicians, who are representatively the best in the city, typhoid fever, according to their observations, has increased in the city since the opening of the Drainage Canal.

(See Dr. Fischel's testimony, pp. 7806-12-14-16; Dr. Saunders' testimony, Vol. 8, p. 7859.)

It is a well known fact that the rise in typhoid fever during the latter part of 1899, prior to the opening of the Drainage Canal, was not due to defective water, but was confined to a certain locality in the city; in other words, it was localized, being confined to what is known as the West End, or the better class of people.

(See Dr. Saunders' testimony, Vol. 8, p. 7597; Dr. Bremer, Vol. 8, p. 7667; Dr. Taussig, Vol. 8, p. 7639; Dr. Goodman, Vol. 8, p. 7664.)

During the past few years the water in the private houses in St. Louis has been filtered to a great extent, and the practice of boiling water has been recommended by physicians, and has been more generally adopted and followed than has been generally supposed. This practice has been followed by the people of the city of St. Louis, and yet the high typhoid death rate has continued to increase.

(See Dr. Bremer's testimony, Vol. 8, pp. 7663-4; Dr. Taussig's testimony, Vol. 8, p. 7640; Dr. Goodman's testimony, Vol. 8, p. 7662.)

The increase in typhoid fever deaths in St. Louis for the period 1900 to 1904, inclusive, over conditions existing for four years immediately prior thereto, was 77.7 per cent, based upon the number of deaths per 100,000 population in the city during the respective years, while the increase in total number of deaths, regardless of population, was 95 per cent.

(Lochridge's testimony, Vol. 8, p. 7936.)

The increase during the winter seasons of the respective periods was much greater than during the summer seasons. The evidence shows that for the period 1900 to 1904, inclusive, over the four years prior thereto, the increase during the winter months was 94.8 per cent for each 100,000 population in the city, while the total increase, regardless of population, amounts during the winter seasons, to 118.2 per cent. The increase during the same season, based upon the 100,000 population table, was 65.7 per cent, and the increase regardless of population was 84 per cent.

(Lochridge's testimony, Vol. 8, pp. 7936 to 7940, inclusive.

As heretofore stated, an attempt was made to discredit the typhoid mortality record of the city of St. Louis as introduced in evidence by complainant. It was charged that the great number of deaths reported by the local physicians as being caused by remittent, intermittent, typho-malaria, malaria, bilious, enteric, typho-pneumonia, congestive and simple continued fevers and published reports of the mortality records of the Health Department of the city were introduced for the respective years for the purpose of showing the reduction of the fevers mentioned. This was objected to for the reason that the reports themselves show that deaths due to other causes were included in the columns remittent, intermittent, etc., it being the contention of the defendants that a large portion of the deaths credited to the aforementioned diseases were, in reality, caused by typhoid fever, and that the total number of recorded deaths from typhoid had been increased on account of the reduction of

the recorded figures for remittent, intermittent, etc. No attempt was made by defendants to show that nothing save remittent, intermittent, etc., were recorded in the column specially set forth for that purpose, or that deaths probably due to these diseases were not embraced by the compiler of the reports in columns under deaths from other causes. In other words, the reports on their face show that no exact conclusions can be based upon them so far as intermittent, remittent, congestive and simple continued fevers, etc., are concerned. In view of this contention, Mr. Lochridge examined the mortality records of the city of St. Louis, including the various death reports made by the physicians of the city and the Health Department, wherein the cause of death was specifically set forth. These reports are copied by the mortuary clerk into large volumes for permanent record; these permanent records were also examined by Mr. Lochridge and from them an accurate compilation of deaths due to the various diseases in question was set forth by the year, the month, giving the age of the decedent, and the location of death, that is, as to where it occurred, in the residence or in one of the many hospitals of the city. This compilation made by Mr. Lochridge shows conclusively no substantial reduction in the reported deaths from malaria, typho-malaria and companion diseases in which the physicians are often times mistaken in their diagnosis, and should be properly classed as deaths due to typhoid fever.

(Lochridge's testimony, Vol. 7, pp. 7823 to 7928.)

From the tables prepared by Mr. Lochridge we reduce the following annual results:

	1896	1897	1898	1899	1900	1901	1902	1903
Remittent fever	40	29	26	15	15	23	17	17
Intermittent fever	12	12	16	25	10	12	9	11
Typho-malaria	50	42	30	31	36	23	34	36
Congestive fever	26	22	13	15	15	4	15	7
Continued fever	1	1	0	0	1	0	1	2
Malaria fever	27	34	23	35	40	28	38	53
Billious fever	11	8	3	6	3	5	7	7

	1896	1897	1898	1899	1900	1901	1902	1903
Enteric fever	0	1	3	2	2	2	2	0
Totals	167	149	116	129	122	97	123	133
Deaths in which typhoid was a cause not included in other table	0	1	1	1	0	2	3	8
Typhoid pneumonia	13	18	17	14	9	18	15	26
Grand totals	180	168	134	144	131	117	141	167

The results as shown by the Lochridge tables are as follows:

Average deaths per annum for the period of four years prior to the opening, 106.5. Average per annum for the four years since the opening of the canal, 208, or an increase of 101.5 deaths per annum during the latter period as compared with the former period.

The average number of deaths reported as due to remittent fever, etc., being 156.5 per annum during the period 1896 to 1899, inclusive, and 140 per annum for the years 1900 to 1903, inclusive. Reducing the annual typhoid increase of 101.5 deaths by the apparent loss or decrease in remittent, etc., of 16.5 deaths, we attain on the basis of defendant's calculation an annual increase of 85 deaths from typhoid, or a percentage increase, upon the total mortality of the city from typhoid, of a fraction over 80 per cent annually. This increase of 85 deaths per annum represents one-fifteenth part of the increase cases per annum, or 1,275.

Valuing the life of the 85 deaths at $5,000, and the loss of labor and expense of treating and nursing the full 1,275 cases while sick for a period of 30 days each, we arrive at a proximate loss to the community and complainant from a financial point of view, as follows:

deaths at $5,000 each	$425,000
are and treatment of 1,275 cases at $5.00 per day for 30 days	191,250
oss of labor of 1,275 persons at $5.00 per day for 30 days	191,250
Total	$707,500

The total loss, financially speaking, is $707,500 per annum, r $2,830,000 for the full period of two years. In addition to is the suffering, distress and resultant injuries cannot, upon rinciples of humanity, be measured in dollars and cents.

ASSIGNMENT OF POINTS OF FACT AND LAW INVOLVED.

1.

A riparian population has the right to the use of a stream for drinking and other domestic uses in its natural state.

2.

Where discharges of sewage render the water of a stream impure or infectious, the injured have a right to ask and obtain relief through the power of the courts.

3.

Even though those residing upon the stream have the right to cast their waste into the stream so long as it does not substantially interfere with the convenience, health and comfort of the business interests of those residing on the river below, yet, such right does not extend to those residing upon another watershed so as to permit such discharges or deposits by artificial means into the stream draining a different watershed.

4.

When discharges have such effect as to render the conditions dangerous and unsanitary, the right to maintain such nuisance can not become permanent by prescription.

5.

The fact that others contribute to the injury constitutes no excuse or justification for the one charged to continue in the same.

6.

The fact that riparian owners are allowed to discharge their waste and refuse into a stream so long as it does not create a substantial injury to those lower down, is merely a privilege even to the law of convenience and public policy. It is not a substantial vested right incapable of defeat.

7.

While the privilege of depositing waste into a river by riparian owners so long as no damage or substantial injury is experienced by those living lower down may be recognized on grounds of public policy and the general law of convenience and necessity of the people, it does not necessarily license others than riparian owners to discharge waste into the stream and that, too, regardless of whether it be a substantial interference with those below the point of discharge or not.

8.

Complainant has been materially and irreparably injured on account of the conduct of defendant in the operation of the artificial channel from Lake Michigan to the Des Plaines river, and the discharge of the raw sewage into the channel and thence into the Mississippi river, defendants having no right in law to convey the sewage of infectious material of two millions people from a watershed above to people living upon another watershed.

9.

Germs of infectious diseases are shown to pass from Chicago to St. Louis and greatly injure the water of the Mississippi at St. Louis, and at all points on the Missouri shore below the mouth of the Illinois river.

10.

The waters of the Mississippi are shown to be more heavily burdened with disease organisms and infectious material since

the opening of the canal, January 17, 1900, than prior to that time, such increased infection being due to the discharge of the sewage at Chicago into the canal.

11.

The typhoid mortality at St. Louis, on account of defendants' action, has increased annually 77.7 per cent for the period of four years since the establishment of the nuisance as compared with the four years immediately prior thereto, such increase of typhoid mortality being due to said nuisance.

12.

Valuing each life to the extent of the annual increase of at least 80 deaths per annum for the four years at $5,000, and the loss of labor, cost of treating and nursing the additional or increased cases amounting to 1,200 (deaths multiplied by 15), occurring annually, calculated on the basis of $10 per day for loss of labor, medical treatment and nursing, it will be observed that the damage of complainant is of no trivial amount.

13.

From the standpoint of humanity and taking into consideration mental and physical suffering, permanent disabilities and all of the disagreeable elements entering into conditions and circumstances which produce death, and taking also into consideration the fact that no one community should attempt to relieve itself from sufferings of sickness and death at the expense of a neighboring community, the right and justice of this litigation instituted on behalf of complainant against defendant, is apparent.

14.

The injury inflicted upon complainant is actual, substantial, continuous, immediate and irreparable.

In the presentation of the case upon the demurrer to the Court, a full line of authorities were submitted upon complainant's right to institute this proceeding, entitling it to judgment if the facts set forth in the petition be established, and showing

complainant's right to join both parties defendant in the action. The position assumed by complainant was upheld, both as to the jurisdictional question and its right to the relief sought. It, therefore, becomes unnecessary for us to again present authorities upon the foregoing propositions. We, therefore, shall confine the presentation of the case to the Court by referring to the important facts established in evidence, together with the legal propositions arising therefrom.

The undisputed evidence shows that disease producing organisms or pathogenic bacteria are discharged from the sewers of a city into the drainage basin and when carried away by the running stream remain in the stream throughout the life of the germ or organism, unless they be sooner introduced into some human system. In this way certain diseases are communicated from one individual to another. As the population of a city upon a watershed increases, the relative number of pathogenic bacteria discharged into the river upon which the city is situated increases, and thus the water of that river is being continually increased in contamination. Experience has shown that by an increase in the number of cases of a particular water-borne disease among persons residing upon a watershed, epidemic conditions are liable to be and often are produced upon the inhabitants of cities taking their water supply from the river in question at considerable distances below the point of infection. Of the water-borne diseases typhoid fever may be said to be the most aggravating. Germs of this disease are known to live for a considerable length of time in water and in sewerage, the length of time depending largely upon the special resistant force of each individual organism. Laboratory experiments have disclosed the life to range in the unsterilized waters of a polluted stream for a period of fifteen to thirty days. It is known to live in the mud and silt of the bed of a stream, being carried there by the process of sedimentation. It lives in moist soil for a number of months. So minute is this particular organism that it is practically impossible to discover it in waters of streams, although it is a known fact that such waters are very often typhoid infected. Sanitarians must, therefore, in passing judgment upon the sanitary condition of a water, take

into consideration the longevity of the germ as disclosed by laboratory experiments, the length of time it is known to live in sedimentation basins and afterwards produce typhoid fever, and also take into consideration the urban population residing on the watershed above the point where the water is being used for domestic purposes; in fact, must consider all the physical facts and surroundings. If it be found that the time for the stream to flow from the point of infection to the water supply falls within the life time of the germ, the water in its natural condition must of necessity be condemned. There is a contrariety of opinion among the witnesses who testified in the case as to the exact longevity of the typhoid organism. There is no disagreement, however, upon the fact that they will live in the waters of the Drainage Canal, at least, six days. This is established by defendants' own witnesses, concurred in by complainant's witnesses, except that they refused to be bound by any fixed time or rule. Governed by the laboratory experiments which assimulate natural conditions in a living water as near as possible, it is safe to say that they will live in the waters of the rivers in question for a period extending beyond thirty days. That they pass from Chicago to St. Louis within the time flow of the water, is in a sense an admitted fact, as shown by the statement of Professor Mason, one of defendants' witnesses, in which he said that there was necessarily a very large reduction in the number of pathogenic bacteria and typhoid organisms as they pass through the canal and down the river, yet undoubtedly some of the highly resistant organisms would survive the journey from Chicago to St. Louis.

Prior to the opening of the canal, the Chicago river had been in a state of putrification and decay. Septic action was continually taking place, the river remaining in this condition practically throughout the entire year. At times of floods and freshets, its contents were gulched into the lake, contaminating the waters of the lake with infectious disease producing organisms, resulting in increased typhoid deaths and cases in the city using Lake Michigan as its water supply. In order to alleviate this condition, the Drainage Canal was constructed, and in doing so, defendants took into consideration only the safety

and convenience of the citizens of Chicago. No regard was had to people living upon the Mississippi river watershed, save that sufficient water was introduced from Lake Michigan to partially destroy the noxious gases which formerly arose from the Chicago river caused by putricient conditions. The introduction of the 250,000 cubic feet of water from Lake Michigan, although seriously contaminated itself, has had a tendency to preserve the life and vitality of the disease producing organisms deposited in the Chicago river from the sewers of Chicago; as all of the witnesses agreed that dilution does not destroy, but rather preserves infectious material.

Not only is the sewage from Chicago conveyed rapidly from that city to St. Louis, but by the addition of the large volume of water from Lake Michigan, the sewage from LaSalle, Henry, Chillicothe, Peoria, Pekin, Beardstown and other points, is carried more rapidly down the Illinois to the Mississippi than prior thereto. So that it may also be safely said that on account of the construction and operation of the canal, the contaminating material found in the Illinois river at its mouth is hastened from the above named points in such time as to preserve the life of a greater number than under conditions existing prior to January 17, 1900.

The population of the Illinois river watershed, based upon the number of square miles of area, exclusive of the city of Chicago, is far in excess of the population residing upon the watersheds of the Mississippi and Missouri rivers per square mile. Indeed, it is an undisputed fact that from the standpoint of population and drainage area, the Illinois river water, aside from the city of Chicago, is far inferior to the waters of the Mississippi or the Missouri. The Illinois river is the only means which nature has prepared for the carrying off of the filth and sewerage of the population residing upon its watershed, and it is now burdened with more polluting and infectious material that is consistent with the requirements of an ordinary safe water supply. When the sewerage from the city of Chicago is added to it, the result, of course, becomes alarming and its passing into the Mississippi river at Grafton, thirty miles above St.

Louis, renders the water of that river in an unwholesome and dangerous condition, as is shown by the increased typhoid mortality of the city of St. Louis.

RIGHT TO USE OF WATER IN ITS NATURAL STATE.

The inhabitants of a large and populous city have the right to use the water of the stream upon which the city is situated in its natural condition, free from infectious material deposited into it at points above. If the discharge of infectious sewerage and filth in the stream renders the waters dangerous and harmful to the people living below, such municipality or person creating the nuisance and causing the danger or damage may be enjoined from continuing the infectious discharges.

Am. & Eng. Enc. of Law, 2nd Ed., Vol. 30, 378.
Indianapolis Waterworks Co. vs. Strawboard Co., 57 Fed. Rep., 1000.
Trevett vs. Prison Association, 98 Va. 352.
Attorney-General vs. Birmingham, 4 Kay & J. 528.
Platt vs. Waterbury, 77 Am. St. Rep., 335.

In Platt vs. Waterbury, 77 Am. St. Rep., 335, the court decided that the use of a stream for drainage may, under some circumstances, be reasonable, although the water is thereby rendered unfit for its primary use, but the concentration of the filth accumulated by one proprietor, whether an individual or a municipal corporation, and its discharge into the stream in such quantities that it is necessarily carried to the premises of another, where it produces a nuisance dangerous to his health and destructive of the value of his property, is unreasonable and creates liability. The right of a city to pour into a river surface drainage does not include the right to mix with that drainage filthy and noxious substances in such quantities that the river cannot dilute them nor safely carry them off without injury to the property of others. The latter act is, in effect, an appropriation of the bed of the river as an open sewer to carry such substances to the property of the lower proprietor and is an invasion of his property rights.

In Trevett vs. Prison Association, 98 Va. 332, the court held that any use of a stream that materially fouls and adulterates the water, or the deposit or discharge therein of any filth or noxious substance that so far affects the water as to impair its value for the ordinary purposes of life; or anything which renders the water less wholesome than when in its ordinary state, or which renders it offensive to taste or smell, or which is naturally calculated to excite disgust in those using the water for the ordinary purposes of life, will constitute a nuisance enjoinable by a court of equity on behalf of the riparian owners residing upon the river below the point of the discharge of the polluting material.

Wood on Nuisances, 3rd Ed., Sec. 427, in this connection said:

"The right of a riparian owner to have the water of a stream come to him in its natural purity is as well recognized as the right to have it flow to his land in its usual flow and volume. But in reference to this, as with the air, it is not every interference with the water that imparts impurities thereto, that is actionable, but only such as impart to the water such impurities as substantially impair its value for the ordinary purposes of life and render it measurably unfit for domestic purposes, or such as causes unwholesome or offensive vapors or odors to arise from the water and thus impairs the comfortable or beneficial enjoyment of property in its vicinity. * * * The polution of water by artificial drainage which causes sewerage to flow into a stream, spring or well, whether done by a municipal corporation or an individual, constitutes a nuisance which entitles the owner to damages therefor, the rule being that a municipal corporation has no more right to injure the waters of a stream or the premises of an individual than a natural person."

Wood on Nuisances, Secs. 427-579.

CONTRIBUTION AND EXONERATION.

Where there are several contributing causes of the pollution and infection of a water course, one cannot escape liabil-

ity for those living below and using the waters for domestic purposes, because of such pollution by themselves. Eliminating from the case the fact that Chicago is situated upon the natural watershed of Lake Michigan while complainant is situated upon the natural watershed of the Mississippi, and even though it be assumed that the same rights with reference to the disposal of its sewerage belong to Chicago as to any other city upon the natural watershed of the Illinois river, it cannot be claimed by the defendants that they have the right to pollute the waters of the Mississippi because there are other cities situated upon its watershed which contribute to the pollution after or before the water reaches the Mississippi at Grafton.

Crossley vs. Lightowler, L. R. 2 Ch. 478.
Tennessee Coal and Iron Co. vs. Hamilton, 100 Ala. 252.
Watson vs. New Milford, 77 American St. 345.
Am. and Eng. Enc. of Law, Vol. 30, 383.

In the case of Hill vs. Smith, 32 Cal. 177, a large number of persons were engaged in mining upon a small stream. It was held by proper proceeding that in as much as each contributed to the deterioration of the water so that the combined acts of all rendered it unfit for use, an action against one cannot be successfully defended on the ground that his act alone did not materially affect the water.

In Little Schuylkill Navigation Co. vs. Richard, 98 Am. Dec. 211, the evidence disclosed that a dam was filled by deposits of coal dirt from different mines on the stream above. Some of these mines were worked by defendants, others by persons entirely unconnected with them. It was held that, while the defendants could not be held liable for the entire injury done, provided the wrong could be supported by means of competent proof, yet the fact that others were contributing to the cause would not justify the perpetration of the act by defendants.

In Ferguson vs. Firmenich Manufacturing Co., 77 Ia. l. c. 579, the Court, in this connection, said: "It is claimed by appel-

lant that Linn Creek * * * has been used as a common sewer by the city and inhabitants of the city of Marshalltown for many years, and was so used during the time in question; that in consequence of such use the water was polluted and rendered, unfit for domestic purposes and for stock and that defendant, at most, could only contribute to the results of which plaintiff complains. But, if that be true, it would not relieve defendant from liability in this action. * * * If the claim of defendant be true, it could not escape responsibility for the wrong because others contributed to it."

In the case of Tennessee Coal and Iron Co. vs. Hamilton, 100 Ala. 252, the Court held, that, while the proper riparian owner may use the waters of a stream and to a certain extent impair its purity, he cannot, however, so pollute it as to render it unfit for the domestic use of lower riparian owners, and in an action instituted by the lower riparian owner for the pollution of the water above, the plea that plaintiff was guilty of negligence contributing to the injury, in that failure was had to take due precautions to prevent it, is insufficient.

In Watson vs. New Milford, 77 American St. Rep. 345, the Court held that a municipal corporation is liable to a lower riparian proprietor for a nuisance created by the discharge of the sewerage of the city into the stream, and although some riparian owner may have previously fouled the stream to the injury of those below him, it does not constitute a license for others to commit similar acts.

The fact that Peoria, Pekin, Havana, LaSalle, Beardstown and Joliet sewer into the Illinois river, does not constitute the right of defendants to likewise discharge the sewerage from the city of Chicago into the Illinois river.

Noland vs. New Britain, 69 Conn. 668.
Wheeler vs. Fisher Oil Co., 9 Ohio Dec. 294.
Jackman vs. Arlington Mills, 137 Mass, 277.

In Morgan vs. Danbury, 67 Conn. 484, the plaintiff, a riparian mill proprietor, alleged that defendant, without making

compensation or attempting to acquire any rights in the premises, is discharging, and threatening to discharge in still greater quantities, waste matter, sewerage and other noxious, corrupt and impure substances from its sewers into the stream so as to pollute it and seriously damage his land and mill privilege; that such discharge poisoned and corrupted the air of the neighborhood and endangered the health of the plaintiff, his workmen and others, and had already partly filled his dam with filth and prevented him from disposing of his land for building purposes. He prayed for an injunction against the continuance of the nuisance, and to restrain the pollution of the water of the stream. The trial court found these allegations to be true, that the plaintiff's injuries could not be adequately compensated in damages, and that the acts complained of constituted a public nuisance, and granted the injunction.

It was held by the appellate court that if the stream was in such condition that the defendant's discharge of the sewerage worked a nuisance, it had no right to use the stream for that purpose, and that the fact that others were contributing to the pollution constituted no defense in the hands of the defendant.

Fahnestock vs. Feldner, 56 Atlantic, 785.

THE RIGHT TO CONTINUE A PUBLIC NUISANCE CANNOT BE ACQUIRED BY PRESCRIPTION.

The fact that Illinois and Michigan Canal was constructed many years ago for the purpose of aiding navigation, and since 1871 has been used for the purpose of partially carrying off the discharges from the stock yards in the southern part of the city of Chicago, and the fact that this canal enters the Illinois river at Peru, does not constitute a right by prescription upon the part of defendants to construct the main drainage canal in question, and operate it in the manner as charged in the bill. Aside from the legal proposition involved, it affords defendants no relief whatever. It may be said that the Illinois and Michigan Canal has never carried from the south fork of the south

branch of the Chicago river more than 10,000 cubic feet of water or sewerage per minute. It has had no marked effect upon the conditions in the Chicago river. After being conveyed into the canal, it required considerable time to pass to Peru on account of its almost imperceptible current. During this period septic action took place and what few pathogenic bacteria remained in it were destroyed. After the Illinois was reached it again met a slow and sluggish current, which, during a greater part of the year, was in a state of quiescence caused by the various dams across the river. No such conditions have existed since January 17, 1900, the date of the opening of the main drainage channel. Since the above date the entire sewerage from a city with a population of two million people has been thrown into the river at Joliet, and by the addition of from 250,000 to 300,000 cubic feet of water per minute has been forced rapidly onward to the mouth of the Illinois river within such time as was absolutely impossible to bring about the death of the disease producing organisms. The construction of the artificial channel and the discharge of Lake Michigan through it has changed conditions entirely in comparison with those which existed prior thereto. So that the fact that a certain portion of the sewerage of Chicago was discharged through the Illinois and Michigan canal prior to January, 1900, does not bestow upon defendants the right either to continue therein or to construct a larger channel capable of producing, and which does produce, irreparable injury to complainant.

In discussing the question as to whether or not the right to maintain a public nuisance can be acquired by prescription, the Court, in the case of Wright & Rice vs. Moore, 38 Ala. i. c. 598, said: "In dismissing the subject, we deemed it proper to remark that there can be no prescription for a public nuisance, and that no length of enjoyment would legalize the continuance of a mill pond destructive of the health of the surrounding community."

In Goldsmid vs. Commissioners, 1 Law Rep. 167, the Court said: "It is to be observed also, which is an observation of im-

portance in this case, that the injury to plaintiff is not confined to his lake, to which so many of the witnesses for defendant direct their testimony, but in fact extends to the whole of his land. But it is important to observe what the position of a gentleman in the situation of plaintiff is. If he comes to the court and complains very early, then the evidence is that it is not perceptible—it is wholly inappreciable—and you get evidence after evidence for the defendants (the pollution being slight and perhaps only observable at some times and on some occasions) saying, 'You have no proof at all that there is any appreciable pollution, and you must wait until it becomes a nuisance.' Then he waits for five or six years until it is obvious to everybody's sense that the pollution is considerable, and then they say, 'You have come too late, you have allowed this to go on for twenty years, and we have acquired an easement over your property and the right of pouring the sewerage into it.' My opinion is that any person who has a water course flowing through his land and sewerage which is perceptible is brought into that water course, has a right to stop it; and that when the pollution is increasing and gradually increasing, from time to time, by the additional quantity of sewerage poured into it, the persons who allow the polluted matter to flow into the stream are not at liberty to claim any right or prescription against him. * * * My firm conviction is that in this, as in all great dispensations and operations of nature, the interests of individuals are not only compatible with, but identical with the interests of the public; and although in this case I have only to consider the injury to a private individual, I believe that the injury to the public may be extremely great by polluting a stream which flows for a considerable distance, the water of which cattle have been in the habit of drinking, the exhalations from which persons residing on the banks must necessarily inhale, and this at a time when the attention of the public and the Court is necessarily called to the fact that the most scientific men who have examined the subject are unable to say whether great diseases among cattle and contagious diseases affecting human beings, such as cholera or typhus and the like, may not in a great measure be communicated or aggravated by the absorption of par-

ticles of feculent matter into the system which are either inappreciable or scarcely appreciable by the most minute chemical analysis. It is impossible in that state of things to say what amount of injury may be done by polluting even partially a stream which flows a considerable distance."

In the case of Mills vs. Hall, 9 Wend. l. c. 416, the Court said: "There is no such thing as a prescriptive right, or any other right, to maintain a public nuisance. Admitting that defendant's dams had been located and maintained for more than twenty years, and that during the whole of that period it has rendered the adjacent territory unhealthy, such length of time can be no defense to a proceeding on the part of the public to abate it, or to an action by any individual for the special and peculiar injury which he may have suffered from it."

In Attorney-General vs. Copper Co., 152 Mass. l. c. 452, the Court said: "We have not overlooked the cases in which it is said that no length of time will legalize a nuisance. The reason of the rule to which these cases refer is, that criminality can gain no toleration in the law. The creation and maintenance of a public nuisance is punishable criminally; hence the element of criminality, which characterizes the act of creating it, should prevent the acquisition of a right to maintain it."

Commonwealth vs. Upton, 6 Gray, 473.
Morton vs. Moore, 15 Gray, 573.
New Salem vs. Eagle Mill, 138 Mass. 8.

In State vs. Rankin, 3 South Carolina, 448, the Court said: "The right to property from long possession, either directly from the operation of the Statute of Limitations, or arising from the presumption of an original cession by grant, cannot be applied to sanction or uphold its use or devotion to purposes not permitted by the State, either as affecting its own sovereignty or the rights of third persons. Chitty, in his 1st volume of Criminal Law, 160, says: 'It has been repeatedly held that no length of time can legalize a public nuisance, although it may afford an answer to an action by a private individual;' and Chief

Justice Parsons, in Town of Sloughton vs. Baker, 4 Mass. 522, observes 'that no laches can be imputed to the government, and against it no time runs so as to bar its rights.' While the long possession may confer a right to the land flowed, and all the proprietory incidents which follow the title to property, it cannot be set up as a bar to the abatement of a nuisance on behalf of the public. A right to violate the law is not to be presumed as allowed by the State itself, for this would be inconsistent with the very purpose for which it was created, and would involve an absurdity too violent to be entertained even for a moment."

NO ONE HAS THE RIGHT TO INCREASE THE VOLUME OR HASTEN THE FLOW OF A STREAM AGAINST THE WISH AND WILL OF LOWER RIPARIAN OWNERS, AND ESPECIALLY IS THIS TRUE WHEN DAMAGE OR INJURY EITHER RESULTS OR IS LIKELY TO RESULT.

Although water may be permitted to run along its natural course and the flow in its natural course may be to some extent hastened, there is, however, no right in law to hasten the flow or impose an additional volume by entering upon the servient estate using artificial channel for drainage purposes, thereby increasing the drainage area and thereby burdening the drainage facilities.

Farnham on Water and Water Rights, Vol. 2, 1052.
Ward vs. Peck, 49 N. J., 4992.

Such an act is a trespass which may be resisted by the injured party, and for that purpose, all the machinery of law is at his service.

Farnham on Water and Water Rights, p. 487.

In passing upon the rights of a riparian owner, it may be said as a general proposition that such owners are entitled to the usual and natural flow of water in the stream without ma-

terial alteration; that is, without the artificial increase or reduction in volume and velocity of current. In the case of the East Jersey Water Company vs. Bigelow, 60 N. J., p. 207, the court said: "It is the right of every owner of land upon a stream to have the water come to him in its natural flow undiminished in quantity and unimpaired in quality, and it may be added, with no increase in the volume except from natural causes. Therefore, it is an actionable nuisance, at common law, for a mill owner or other person to turn a new stream into the stream, or by means of a reservoir to increase the volume of water naturally flowing into the stream and it is no defense for an action for such an injury that the person complaining is benefited by the increase of the volume of water for no person can be compelled to have his premises improved and has a right to their enjoyment in their natural condition according to his own tastes and inclination."

Wood on Nuisances, pp. 499 and 500.

In Merritt vs. Packer, First Coxey, 496 to 533, Chief Justice Kinsey said: "It would be equally unreasonable that any man should have the right to turn more water over the land of his neighbor than would naturally come in that direction, and so far as regards the right, it is altogether immaterial whether it be productive of injury or benefit. No one has the right to compel another to have his property improved in any particular manner. It is as illegal for him to receive the benefit as to submit to the injury."

Tillotson vs. Smith, 32 N. H., 490.

Gerrish vs. New Market Manufacturing Company, 30 N. H., 478.

In Plattsworth Company vs. Smith, 57 Neb., 579, it is held that riparian owners are entitled to the right of usual water flow in a water stream without material alteration.

In Tillotson vs. Smith 32 N. H., 490, the court, speaking through Judge Bell, said: "Every owner of land situate upon

a stream has a right to the natural flow of the stream; a right to insist that the stream shall continue to run uti curren solebat; that it shall flow upon his land in its usual quantity at its natural place and at its usual height, and that it shall flow off his land upon the land of his neighbor below in its accustomed place and at its usual level. This right has been as an incident to the water of his land and he can not be deprived of it but by grant, actual or presumptive. Whenever, by reason of the interference of the owner above, the water is diverted from his land and made to run elsewhere, or the water of other streams, naturally running elsewhere, is turned upon his land, or the water of the natural stream is made to flow upon his land at a different place from its natural channel, or at a different level, or in an unnatural manner, and so, whenever, by the acts of the owner of the land below, the water is obstructed, or drawn down or made to run off in an unusual place or in an unusual manner, and actual injury ensues to any material amount, the owner of the land may maintain an action for such injury. In short, if any person, above or below, shall make any change in the natural flow of the stream, to the material injury of the owner situate upon it, or by any interference shall prevent the stream from flowing as it was wont to flow, to such injury, he is liable for the damage he may occasion. These rights are subject to the rights of the owners of the land situate above and below upon the stream to make a reasonable use of the water upon their own land while it is passing along the same.

The precise case before us, which is of a class of which the instances are comparatively unfrequent, that of turning a stream from its natural channel and forcing it to run in the channel of another stream, was decided in Merrill vs. Parker, Coxe, 460, cited in Agnell on Watercourses, 335. The point as it arises in the French law is fully discussed in Pardessus and Servitudes, Secs. 82, 85, 88. It seems very evident that if a man's land is materially damaged by water thrown upon it by reason of the acts of another, it can make no difference what the source of the water may be; whether it be backwater, or the flowage of the same, or the water of another stream. The wrong consists in turning any water upon the land which does not naturally flow

in that place; and it can make no difference if the water wrongfully turned upon a man's land against his will flows in the channel of an ancient stream, or in a course where no water flowed before, if similar damage results: Howell vs. McCoy, 3 Rawle, Huston, J.; Bealey vs. Shaw, 6 East, 213, Ellenborough, C. J.; Mason vs. Hill, 3 Barn. & Adol., 304, Tenterden, C. J.; King vs. Tiffany, 9 Conn., 162; 3 Kent's Com., 439.

It is a long established principle of the common law that wherever any act injures another's right, and would be evidence in future in favor of the wrong-doer, an action may be maintained for an invasion of the right without proof of any specific injury: Mellor vs. Spateman, 1 Wms. Saund., 346, note 2. This principle has been recognized here in the case of Woodman vs. Tufts, 9 N. H., 91; Snow vs. Cowles, 22 Id., 302; Cowles vs. Kidder, 24 Id. 379; Bassett vs. Salisbury Mfg. Co., 28 Id. 455. In the last case it was held that the state of the plaintiff's interest might be properly inquired into, because, if he sustained no damage in fact, and had no interest that could be affected by the danger of an accruing easement, he might not recover any damages. That is not the present case. The plaintiff appears to be owner in fee."

In connection with the foregoing, we call the Court's attention to the following:

Evans vs. Merriweather, 38 A. Dec., 106.
TenEyck vs. Delaware Canal Co., 32 A. Dec., 232.
Miller vs. Miller, 39 A. Dec., 544.
Norton vs. Valentine, 39 A. Dec., 220.
Elliott vs. Fitzbury 57 A. Dec., 85.
Newhall vs. Iresom, 54 A. Dec., 794.

Applying the doctrine of the foregoing cases to the facts here involved, we submit that complainant has the right to the use of the Mississippi river in its natural and accustomed flow; that defendants have no right to change or alter the velocity of the stream or the volume of water passing down it. By the increased volume of water discharged into the Illinois river not

only is the height of the water increased, but also the velocity likewise becomes much greater, the particular damage resulting to complainant in this respect being that in as much as the velocity of the current and the volume of water is increased, the longevity of disease producing organisms is greatly advanced and the rapidity with which they pass from Chicago to St. Louis is largely accelerated. As shown by all of the evidence in the case, this constitutes a material and substantial, in fact, a great damage and injury to complainant. There being no contrariety of opinion that by the increase in the volume of water the life of the disease producing organisms is greatly increased, and likewise, by the increase of the current, the distance traveled by pathogenic bacteria within their life time is largely extended.

The above and foregoing facts constitute really the basis of the damage and injury complained of. It is a matter of no consequence as to the manner in which damage results from those living below on account of the increased volume or velocity of the stream. The application of the principle of law in question is the same, whether it comes in the way of destruction of property, or whether by overflowing the land or the carrying away of dams and docks, or whether it come by carrying large quantities of infectious matter which, when taken into the human system, when the water is used for domestic purposes and creates disease. In fact, if there be a consequential difference, it would be more important for the courts to protect lower riparian owners from an increase in the volume and velocity of the streams on account of the quickening of the passage of infectious material and of the increased quantity of such infection that may be thrust upon the population at a given point below.

When we consider the fact that no scientific observer has yet been able to formulate a table showing the exact longevity of disease producing organisms deposited into running streams, and when we take into consideration the fact that the longevity of such germs depend largely upon physical surroundings and atmospheric conditions, together with the admitted fact that such germs exist in water for a considerable length of time. there is no way to avoid the conclusion that the greatest of care and precaution should be exercised by those having in

charge the duty of determining whether or not a given water is the cause of the unwholesome conditions of a city using the water of the river for domestic purposes, especially is this true when the fact also stands admitted that large quantities of sewage from a community populated with two millions of people is discharged into the river at a point above the city in question.

Defendants, by means of the artificial channel which has been constructed from Chicago river to the Des Plaines river, deposit large quantities of infectious material in the water, starting it on its way from the source of infection, subjecting all persons residing upon the river below that point to its damaging results. There is no testimony from a practical sanitary standpoint that enables one to draw the conclusion that at all times and seasons of the year under the various changing conditions of the river that it has become freed from its pathogenic bacteria before the Mississippi river is reached at Grafton. This condition is emphasized when it is known that the velocity of the river varies considerably. Even though it be admitted that during exceedingly low stages of the river more time is required for the flow to reach the Mississippi, that the polluting material becomes largely concentrated, a large portion of such infection or pollution may disappear within a given time, and that, too, before the mouth of the river is reached, but such conclusions can not be made applicable to conditions when the river is at flood, or during the winter seasons when saprophytic action is limited and septic conditions practically removed from the water. Nor will it be sufficient to destroy the more persistent and highly vitalized pathogenic bacteria.

The evidence shows that a number, in fact all, of the typhoid epidemics of consequence have been produced by infectious water. The epidemic at Washington in 1898, caused by a typhoid epidemic at Cumberland, Maryland, 175 miles up the stream; the epidemic at Detroit, caused by typhoid germs being deposited in the St. Clair river at the mouth of Black river, a distance of 67 miles from Detroit, and where the water was required to pass through St. Clair river and Lake St. Clair before it reached

the intakes of the Detroit waterworks; the epidemic at Lawrence and Newport, where the water was inducted into large reservoirs and so remained for a period of from two to three weeks, and yet preserved sufficient of the typhoid bacteria, alive and virulent, to produce the disease. The epidemic at Pittsburg, Penn., caused by typhoidal conditions at Oil City, 113 miles above. In addition to what may be said with reference to the epidemics, it may also be said that the unusual high typhoid death rates occurring in various localities throughout the country, have been attributed to infected water supplies. Cincinnati, Ohio, with a high typhoid mortality, receives its water supply from the Ohio river, and is known to be infected from the sewers of Pittsburg, a distance of more than 200 miles away; Buffalo, which obtains its water supply practically from the mouth of Lake Erie, suffers with a high typhoid mortality, caused by the sewage discharge into the Lake at Cleveland and other points. Covington, Kentucky, and New Albany, Ind., suffer severely from the disease. At these points the water is pumped into large reservoirs, where it is confined for more than 30 days, during which time it retains sufficient germs of the disease that when distributed to the consumer, typhoid conditions result. The city of Chicago, one of the greatest typhoid-ridden cities in the United States, takes its water supply from Lake Michigan, heretofore looked upon as an acceptable source for pure water. The experience of the city, however, has demonstrated that the sewage from Chicago itself has so contaminated and infected the water of the Lake at such distance from the shore so as to render it questionable whether the intakes could be extended a sufficient distance into the Lake to be free from infectious material. (See Rudolph Herring's testimony, Vol. 8, pp. 740 to 742, inclusive.)

In his testimony in Vol. 8, page 719, Dr. Barker, one of defendant's witnesses, testified that the city of Toronto suffered with typhoid due from the infectious condition of the water of Lake Ontario, that the intakes were situated about three miles out from the shore, and that, in order to be secure from the contaminating effects of the sewage of the city, it would be necessary to extend those intakes a distance of 100 miles. This, of

course, would reach far across into the state of New York, but demonstrates the fact that even the large lakes of the country may become subject to infectious material even to their very centers.

Prof. Mason, at page 6960 and 6961 of the printed record, stated in his opinion that in consideration of the facts regarding the Chicago sewage being dumped into the Illinois river as at present, and the facts concerning the infection of the Illinois river with the germs of typhoid fever coming from the sewers of that city, such germs would be largely destroyed by the time the mouth of the Illinois is reached, although some resistant organisms would pass beyond that point, some typhoid germs having greater vitality than others, resembling largely a crop of turnips grown upon good soil as compared to a crop grown upon poor soil; that all things considered, it is impossible to tell what is the longevity of specially resistant cells, experimental data having shown that for the general mass the longevity is fairly well fixed, but that with reference to a great many, and especially the highly resistant individuals, we are still in total ignorance.

Dr. E. G. Smith, also one of defendant's witnesses, testified that the population residing upon the watershed of the particular stream in question is of great importance, and that as the population increases, the sanitary condition of the water will naturally become inferior. Dr. Smith also stated that the water in a running stream is continually changing from day to day and likewise the saprophytic influences c' ange. Oxidation, sedimentation, dilution, in fact, all of the factors which enter into the destruction or preservation of pathogenic bacteria, do not remain the same for any considerable length of time. Recognizing the infectious conditions of a running stream due to typhoid bacilli, Dr. Smith, as consulting sanitary engineer for the waterworks situated at Beaver Falls, in 1903, after hearing of the typhoid epidemic at Butler, Pennsylvania, a town situated 72 miles above, wrote to the waterworks company of that place warning them against permitting the raw water to be taken into the reservoirs without filtration and to be exceedingly care-

ful in the operation of the filtration plant else typhoid conditions would become prevalent in the latter city, rendering the company liable for damages on account of inferior water supplied.

(E. G. Smith's testimony, Vol. 7, pp. 6828 to 6846.)

Profs. Long and Palmer, who conducted a series of chemical analysis of the waters of the respective rivers and Lake Michigan, stated in their cross-examination that pathogenic bacteria could not be observed from a chemical standpoint or by means of chemical analysis; that there was a certain nitrogenous residue exposed in the analysis, which, of course, contained the living organisms, if there be any, but as to the character of such living organisms, no determination could be made.

(See Long's testimony, Vol. 5, p. 3496, and Palmer's Vol. 5, page 3462 to 3467, inclusive.

Prof. Jordan, at page 6344 to 6345 stated that in his opinion "the most convincing evidence of the presence of typhoid bacilli in a given water during a given period would be the tracing of typhoid to that water, it being assumed that other sources of infection were sufficiently well examined to permit the establishment of the conviction that the particular water under consideration at the particular time stated, was responsible for the production of the cause of typhoid fever;" and, that "the best evidence as to water being typhoid infected is the result which it produces upon a community using it for domestic and drinking purposes," that there is no royal road to the accomplishment of determining the existence of pathogenic bacteria in water.

We, therefore, submit to the court that, in view of all the unquestionable facts and circumstances presented by complainant, together with the fact that defendant discharged disease germs into the canal, coupled with the fact that there has been an increase of 77.7 per cent of the typhoid mortality in the city of St. Louis, it is apparent that pathogenic bacteria do pass from

Chicago to the Mississippi river at Grafton and seriously affect the sanitary condition of complainant's water supply.

One of the most remarkable disclosures in this investigation is found by the discovery of the bacilli of anthrax and tentinus in the waters of the Illinois river. This discovery was made by Prof. Zeit in his bacteriological observations of the water since the opening of the drainage canal.

Not only has the act of defendants been damaging to the people of the city of St. Louis, which constitutes one-third of the population of complainant, but also renders unsuitable the water supply of the people residing upon the Mississippi river from a point opposite Grafton to the Southern boundary line of the State.

Prior to the opening of the drainage canal, the city of St. Louis was furnished with a water supply equally as good as that obtained by a majority of the great cities of the country, its typhoid mortality being as low as that of Boston and lower than that of Chicago, Philadelphia, Buffalo, Cleveland, Baltimore and Cincinnati. Since that date, it has lost its former position and now assumes rank in the second class of cities, furnishing the greatest number of typhoid fever deaths per one hundred thousand population.

This increase of typhoid in St. Louis has gradually grown while physicians have advised the use of private filters and boiling of water. This advice has, to a large extent, been followed, and the practice of following it has gradually increased. The natural effect looked for would be a reduction in the number of typhoid cases; we, however, have an opposite result.

Considering the loss of life, the mental and physical suffering, along with the cost which typhoid conditions bring to a community as well as the harm done to the commercial interests of the State, we can appreciate only partially the injury inflicted upon complainant by the careless manner in which the sewage of Chicago is deposited into the Illinois river. It is not only encumbent upon the public to look well after the health of the people in every regard, but also important that water sup-

plies receive careful and proper attention. Typhoid fever is termed by scientists as a disease of civilization. "For every death from it, someone is criminally liable." While it is true, it may be impossible to eradicate it, but sufficient has been learned in recent years to know that it can be largely reduced and avoided.

Applying this application upon the part of the public, to the facts as herein shown to exist, and the points of law heretofore enunciated, we submit that complainant has the right to ask the interference of the court to compel the State of Illinois and the Sanitary District of Chicago to forego the discharge of the sewage of the city of Chicago into the Illinois river. No objection is here made to the construction of the canal or of the transmission of water from Lake Michigan through it. It is, however, insisted that in as much as defendants disregarded their plain duty by failing to put its sewage through a course of treatment, removing from it the infectious material, before being discharged into the canal, they should now, either, be required to subject it to such treatment or discontinue its discharge into the river.

While we have thus spoken of conditions that exist at the present time, and have existed since the opening of the drainage canal, January 17, 1900, we have not referred specifically to conditions which will unquestionably occur in the near future, unless some remedy be afforded complainant. The Illinois river is now burdened to its limit in caring for the waste, filth and sewage deposited in it by the people residing upon its natural watershed. The population upon the Mississippi and Missouri rivers will naturally grow; and will grow rapidly. The city of Chicago, judging its future by the past, will not remain as it is. The time is not far distant when we may expect a population of five millions of people in that municipality. It is therefore natural to believe that ere long the waters of the Mississippi river below Grafton will become more contaminated with infectious material so as to increase the typhoid mortality of all cities taking from it their water supply. Complainant, therefore, asserts its right to preserve its waters in their natural con-

dition as near as may be consistent with the convenience and good of its own people. It, therefore, asks that its prayer as set forth in its bill heretofore filed, be granted.

Respectfully submitted,

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Clerk.

IN THE

Supreme Court of the United States.

OCTOBER TERM, 1905.

STATE OF MISSOURI, *Complainant,* *vs.* **STATE OF ILLINOIS and the SANITARY DISTRICT OF CHICAGO,** *Defendants.*	**ORIGINAL NO. 4.**

HERBERT S. HADLEY,
Attorney-General of Missouri,
CHARLES W. BATES,
City Counselor of St. Louis,
For Complainant.

SAM B. JEFFRIES,
Of Counsel.

THE HUGH STEPHENS PRTG. CO., JEFFERSON CITY.

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STATE OF MISSOURI, *Complainant,* *vs.* **STATE OF ILLINOIS and the SANITARY DISTRICT OF CHICAGO,** *Defendants.*	**ORGINAL NO. 4.**

STATEMENT.

In the original brief filed by complainant the bill of complaint was set forth at length and an extended review of the testimony introduced to sustain the allegations of the complaint.

The State of Illinois and the Sanitary District of Chicago, defendants, have since filed their brief, setting forth at length their answers and the testimony offered by them.

In order that the concrete issues of fact now before this court for decision may be more succinctly presented, and the testimony set forth by complainants and defendants in their briefs may be more clearly understood in their application to the pleadings, complainant asks the indulgence of the court to submit a brief statement as to the actual issues of fact upon which this cause is to be determined.

I.

ISSUES MADE BY THE PLEADINGS.

The State of Missouri, in its bill of complaint, alleged that the Sanitary District of Chicago, acting under the authority of the State of Illinois, constructed a channel or open drain from the Chicago to the Desplaines river, which in turn empties into the Illinois, and which latter river empties into the Mississippi at a point about thirty-eight miles above the city of St. Louis; that said channel was constructed by said defendants in order that the sewage of the city of Chicago might be discharged into the Chicago river, thence into said channel, which is known as the drainage canal, thence into the Desplaines river, thence into the Illinois river, and finally into the Mississippi; that by the construction of said canal the natural drainage of the Chicago river into Lake Michigan was reversed so as to flow into the Mississippi river; that there was daily caused to flow from the Chicago river, through the drainage canal, into the Desplaines, thence through the Illinois river into the Mississippi, about fifteen hundred tons of sewage from the city of Chicago; that a large portion of the population of the State of Missouri lived upon the Mississippi river below the junction of the Illinois and Mississippi, and that it is necessary that such population should secure its water supply from the Mississippi by taking therefrom the water into waterworks systems, etc., and that they had done so for time beyond which the memory of man runneth not to the contrary; that by reason of the discharge of the sewage of Chicago into the Mississippi river, as aforesaid, the water of that river was rendered unfit for use, injurious to the health of the people of the State of Missouri, and constitutes a nuisance.

An injunction was asked against the defendants that they be restrained from permitting the sewage of Chicago to be discharged into said artificial channel or canal, and that they be restrained from receiving such sewage into said canal.

The defendants, by their separate answers, admitted the construction of the artificial channel or canal, as alleged in the bill of complainant, and that it has received and is receiving into said channel the sewage matter of the sanitary district of Chicago, and has caused said sewage to flow through said channel or canal into the Desplaines river.

Defendants deny that said sewage would be or is injurious to the lives or health of the people of Missouri who drew their water supply from the Mississippi river.

Defendants also allege that for a long number of years a large portion of the sewage of the city of Chicago had been discharged through the Illinois and Michigan Canal into the Desplaines river, thence into the Illinois river, and from there flowing into the Mississippi; that a large number of other cities situated upon the Mississippi river discharge their sewage into that river above the point where the Illinois flows into the Mississippi; and that a large number of cities are likewise situated upon the Missouri river and discharge their sewage into that river.

The one controlling question of fact in the case is as to whether the sewage of the city of Chicago, thus discharged into the Mississippi river, affected the water of that river so as to endanger the health and lives of the people of the city of St. Louis.

The testimony offered by the complainant and defendants was in support and denial of this concrete question of fact.

II.

FACTS DISCLOSED BY THE TESTIMONY.

In the year 1900 the city of St. Louis, situated on the west bank of the Mississippi river, was a city of about 650,000 people. About 20 miles above the city of St. Louis the Missouri river joins the Mississippi from the west; and about 38 miles above the city of St. Louis the Illinois river flows into the Mississippi from the east. Near the city of Joliet, in the State of Illinois, by the junction of the Desplaines and Kankakee rivers, the Illinois river is formed. At Lockport, a short distance above the city of Joliet, the Chicago drainage canal joins the Desplaines river, connecting that river with the south fork of the Chicago river at Robey street in the city of Chicago.

The drainage canal is an artificial channel cut through the natural divide that separates the waters that drain into Lake Michigan from the waters that drain into the Mississippi. It is 28.05 miles long, 110 feet wide on the bottom, and the average depth of the water flowing there-through is 22 feet.

The distance from the city of Chicago along the course of the Chicago river, drainage canal, Desplaines river and Illinois and Mississippi rivers to the city of St. Louis is 357 miles.

The drainage canal was opened for use on the 17th day of January, 1900, and at that time the city of Chicago had a population of nearly two millions.

The nearest city to St. Louis located upon the Missouri river is Kansas City, with a population of 165,000, and which is 418 miles distant, according to the course of the river.

Between the cities of Minneapolis and St. Paul and the city of St. Louis, a distance of 617 miles, no cities located upon

the Mississippi river possess as large a population as forty thousand. The largest of these cities are Quincy, Ill., 36,000, 141 miles distant; Burlington, Ia., 23,000, 217 miles distant; and Dubuque, Ia., 36,000, 279 miles distant.

On the Illinois river there are located the cities of Peoria, with a population of thirty odd thousand, about 200 miles distant from St. Louis; Pekin, opposite Peoria, with a population of about 9,000; LaSalle and Peru, whose combined population is about 18,000, 100 miles distant from Chicago, and 254 miles from St. Louis.

About the year 1895 the city of St. Louis constructed an extensive waterworks system, with the intake tower at a point in the river 1,500 feet from the west bank of the Mississippi river, known as the Chain of Rocks, about eight miles above the Eads Bridge, and five miles above the northern limits of the city. For many years prior to that date St. Louis had drawn her water supply from the Mississippi river, the point of intake being where the Merchants' bridge now crosses the Mississippi, near the northern limits of the city.

Prior to the construction and opening of the drainage canal the city of Chicago discharged its sewage into the Chicago river, where a large portion of it remained until it was carried by high water into Lake Michigan. A small portion was pumped from the south branch of the Chicago river into the Illnois and Michigan canal, from which it flowed into the Desplaines river, and from thence into the Illinois river. The great mass of the Chicago sewage, however, remained during the greater part of the year in a stagnant condition in the Chicago river. In times of flood and freshets this mass of putrifying material contained in the river was pushed out into Lake Michigan, infecting the source of the water supply of the city of Chicago,

located from four to six miles from the western shore of Lake Michigan.

It was for this reason that the sanitary district of Chicago was created, and the Chicago drainage canal was constructed.

POPULATION OF MISSISSIPPI, MISSOURI AND ILLINOIS RIVER WATERSHEDS.

As the density of population upon any watershed is an important factor in determining the condition of a river which is relied upon to carry away the sewage of such population, it is well to note the urban population upon the Mississippi, Missouri and Illinois watersheds, exclusive of that population which resides within the sanitary district of Chicago.

The Missouri river has 2.1 population to one square mile; the Mississippi river, above St. Louis, 4.2 population to one square mile; the Illinois river, 16.7 population to one square mile. The Mississippi river, above St. Louis, including the Missouri and the Illinois watershed, has 3.2 population to one square mile.

The population of the Sanitary District of Chicago at the time of the opening of the drainage canal amounted to about two millions. The construction of this canal, changing the flow of the Chicago river from Lake Michigan into the Mississippi, increased the density of population on the Mississippi watershed above St. Louis from 3.2 population to one square mile to 5.6 population to one square mile, an increase in the population discharging its sewage into the Mississippi river above St. Louis of 2.4 to one square mile.

Thus the population of the Illinois river watershed and of the Sanitary District of Chicago, added by the construction of this canal to the Illinois watershed, were greater than the population of the Missouri river and upper Mississippi river watershed combined. And the addition of the population of the Sanitary District of Chicago to the watershed of the Illinois increased its population 520 per cent.

The urban population residing upon the Missouri river watershed, according to the census of 1900, was 1,090,832, and the urban population residing upon the Illinois river, exclusive of the city of Chicago, 385, 305.

The population residing upon the Mississippi river watershed above St. Louis, exclusive of the Missouri and the Illinois rivers, according to the census of 1900, was 1,219,645.

The population of the Sanitary District of the city of Chicago, added to the population of the Illinois watershed, is greater than the combined urban population of the Missouri river and Illinois watersheds, and also greater than the urban population of the upper Mississippi and Illinois watersheds; while the combined urban population of the Illinois watershed and the Sanitary District of Chicago exceeds the combined urban population of the Missouri river and the Mississippi river above the mouth of the Illinois.

TYPHOID FEVER IN CHICAGO AND ST. LOUIS PRIOR TO THE OPENING OF THE DRAINAGE CANAL.

As the principal contention of complainant in this case is that the opening of the Chicago Drainage Canal and the discharge of the sewage of Chicago thereby into the Mississippi river infected the water supply of the city of St. Louis and largely increased typhoid fever in that city, it is important to note the number of cases of this dread disease that existed in the two cities prior to the opening of the Chicago Drainage Canal.

In the city of St. Louis the death rate per hundred thousand inhabitants was as follows: 1896, 20.2 per hundred thousand; 1897, 23.4 per hundred thousand; 1898, 17.3 per hundred thousand; 1899, 20.3 per hundred thousand.

Since 1895 there has been no change in the source of the water supply of the city of St. Louis, or in the manner of its treatment.

Since January, 1900, typhoid fever in St. Louis has increased 77 per cent, as compared with the period immediately prior thereto, from 1895 to 1899, inclusive. This increase in typhoid fever was gradual and of a permanent character, bearing no evidence of frequent occurrence and disappearance, therefore becoming entirely disassociated from the effect of local epidemics which are usually confined to a certain district or locality in a given city. The number of deaths from typhoid fever per hundred thousand population occurring in St. Louis for the years 1900, 1901, 1902 and 1903 were as follows:

1900, 30.2
1901, 33.5
1902, 36.7
1903, 46.5

Or, as above stated, an increase of 77 per cent in the mortality rate from this disease after the opening of this canal, as compared with the mortality rate from 1895 to 1899, inclusive.

The number of deaths from typhoid fever in the city of Chicago from 1896 to 1902, inclusive, were as follows:

1896,	751
1897,	437
1898,	636
1899,	449
1900,	442
1901,	509
1902,	801

Complainant also introduced evidence showing that, prior to the opening of the Drainage Canal, St. Louis was possessed of a reasonably safe water supply equal to that of the city of Boston and other large municipalities throughout the United States; that since the opening of the Drainage Canal, its water supply had become unsafe, as shown by the increased number of deaths per hundred thousand from typhoid fever.

CAUSE OF INCREASE OF TYPHOID FEVER IN ST. LOUIS.

The testimony shows that the increase in typhoid fever mortality since January, 1900, at St. Louis has been due to the increased infection of the St. Louis water supply by the infectious material coming from the sewers of Chicago.

A thorough study and examination was made of all local conditions which might have caused or contributed to such increase. This examination extended to the use of milk in the various localities of the city, and also to the use of wells in those localities where the population had become accustomed to the use of well water, or where it was necessary to use such water. It was found that neither of these conditions contributed to such increase. This finding is verified by the fact that the increase was uniform throughout the city, being as large in those districts where there were no wells as in those where well water was relied upon and used to a considerable extent for domestic purposes.

The examination made presented facts which also precluded the possibility of the increase in typhoid fever being caused by the use of impure milk.

The next step in the investigation was along the lines of possible exclusion and inclusion by the examination of typhoid conditions from 1895 to 1903 in the various cities which discharge their sewage into the Missouri and Mississippi river above St. Louis and the Illinois river, exclusive of the Sanitary District of Chicago. This determination was made by examining the mortality records of the various cities on the said rivers, with the result that no increase in typhoid fever was found to have occurred in any of said cities throughout said period, thus precluding the possibility of the increase in ty-

phoid in St. Louis being attributable to an increase in typhoid in any of the cities upon the Missouri, Mississippi or Illinois rivers, exclusive of the Sanitary District of Chicago.

The testimony having disclosed a 77 per cent increase in typhoid fever in the city of St. Louis following the opening of the Chicago Drainage Canal, and having also disclosed no increase in those cities whose sewage for years prior to January, 1900, had been discharged into the Missouri, Mississippi or Illinois rivers above St. Louis, and the testimony having also disclosed the absence of any local conditions to which this increase in typhoid fever in St. Louis could be attributed, the next point of importance in the testimony relates to the amount of sewage discharged by the city of Chicago through the Drainage Canal, the Desplaines and the Illinois rivers to the Mississippi above St. Louis; the amount of typhoid bacteria contained in said sewage; and as to whether such typhoid bacteria would survive from the point of discharge at Chicago to the time the water in which they were contained was consumed by the people of St. Louis.

AMOUNT OF SEWAGE PRODUCED BY THE CITY OF CHICAGO.

Upon this point, the testimony showed that the amount of sewage discharged by the city of Chicago into the Chicago river and from thence into the Drainage Canal, amounted to three hundred and fifty million gallons of raw sewage per day. Sanitarians testified that for each inhabitant of a sewered town there was a discharge of one hundred and seventy-five gallons of raw sewage. This sewage would amount to 47,250,000 cubic feet a day. The amount of solid excrementations matter and urine coming from each person is estimated by experienced sanitarians at 43 ounces per day. With each of the 2,000,000 people of Chicago discharging 43 ounces of such matter per day, the total of such discharge amounts to more than 190 tons per 24 hours, or 380,000 gallons. The testimony shows that there was in Chicago in the year 1900 6,630 cases of typhoid fever, which would result in 1,187,875 pounds of solid typhoid infectious matter being discharged during such period into the Chicago Drainage Canal. In view of the fact that the testimony shows that after one has recovered from typhoid fever he continues to throw off typhoid bacteria for a period of several years, the maximum amount of sewage infected with typhoid germs discharged daily by the inhabitants of Chicago becomes impossible of calculation. Taking the number of typhoid patients as a minimum, the amount of sewage directly infected with typhoid bacteria at the time of its discharge into the Chicago river makes the astounding total of 4,235,250 gallons each month.

The testimony shows that an ordinary case of typhoid lasts for a period of not less than forty days. Also, that the total

number of deaths from typhoid in the city of Chicago for the year 1900, which is less than any year subsequent and for several years prior thereto, was 442, which multiplied by 15, in order to obtain the approximate number of cases taking place, it will be found that there were during that year 6,630 cases, and as each of these cases lasted for a period of not less than forty days, there were on an average of 921 persons in the city of Chicago sick with typhoid fever throughout the entire year. These typhoid infected persons, on the generally accepted basis of 175 gallons per day for each inhabitant, would produce 124,200 gallons of sewage each day. Therefore, taking the minimum amount of typhoid infected sewage produced by the city of Chicago, as shown by the evidence, would amount to 5,175 gallons each hour, or 124,200 gallons a day, as aforestated. The number of typhoid bacilli contained in this infected sewage is impossible of even approximation, as every cubic centimeter of discharge from a typhoid fever patient is supposed to contain from one to four million typhoid bacteria.

MOVEMENT AND DILUTION OF SEWAGE FROM CHICAGO TO ST. LOUIS.

The sewage discharged by the city of Chicago into the Chicago river is diluted, as shown by the testimony, by 250,000 cubic feet of water from Lake Michigan, which is forced through the Chicago river and thence through the Drainage Canal; the proportion of water to sewage being nine to one. This amount of water forced into the Chicago river, flowing thence to the Chicago Drainage Canal, thence to the Desplaines, Illinois and to the Mississippi has created a flow through such channels by which water and sewage from Chicago is brought to the intake of the St. Louis waterworks in from eight to eighteen days.

The testimony shows that a period of forty-eight hours elapses from the reception of the water of the Mississippi river at the intake of the St. Louis waterworks until it is distributed to the consumers throughout the city. Thus the period from the Chicago river, where the sewage of Chicago is discharged, to the mouths of the people of St. Louis is, as shown by the testimony, from ten to twenty days.

DURATION OF LIFE OF TYPHOID BACTERIA.

The important question for determination in this case is as to whether the typhoid bacteria discharged by the people of Chicago survive during this period of ten to twenty days and produce the 77 per cent increase in the mortality rate of that dread disease in the city of St. Louis. Upon this question the complainant offered testimony as to actual conditions which by a process of exclusion and inclusion necessitates the conclusion that the increase in the typhoid fever in the city of St. Louis could be attributed to no other cause than the flowing of Chicago sewage into the St. Louis water supply.

There was also offered in evidence the testimony of a large number of the leading bacteriologists, epidemiologists and sanitarians of the United States, who gave it as their confirmed opinion, from a careful and comprehensive investigation of the facts, that the typhoid bacteria passing from the people of Chicago lived from the time of their discharge into the Chicago river until the water in which they were contained was taken from the waterworks system of St. Louis city by the people for domestic purposes.

It is conceded by the experts, both for the complainant and for the defendants, that the dilution of the sewage of Chicago by the water from Lake Michigan tended to increase the duration of life of the typhoid bacteria instead of decreasing the period of their existence. The reason for this preservative effect of the diluted water upon pathogenic bacteria is that in ordinary water and sewage the bacteria, commonly known as saprophytes, are so far removed from each other and from the pathogenic or disease producing bacteria as to be incapable of

bringing about the destruction of the latter. The formerly accepted theory that running water purifies itself of pathogenic bacteria by virtue of the fact that it is running water, was pronounced a popular delusion by both the experts for the complainant and the defendants. The fact that stagnant water purifies itself of disease producing germs was also agreed to by all the experts in the case and that this result was accomplished much more rapidly in stagnant water than in running water. This was explained by the fact that certain germs which are found in sewage, known as saprophytes, which are non-disease producing germs, prey upon and destroy the disease producing organisms which are known as pathogenic bacteria or parasites. In stagnant water, therefore, saprophytic germs have an opportunity to "get in their work" on pathogenic bacteria, while in running water, or water in which the sewage containing pathogenic bacteria is highly diluted, a better opportunity for escape is offered to the disease producing germs.

OPINIONS OF EXPERTS.

The experienced witnesses, who testified on behalf of the complainant, stated that in their opinion typhoid bacteria were able to pass from the sewers of Chicago to the city of St. Louis in sufficient quantity and vitality to produce typhoid infection among the people of St. Louis, and that the increase in typhoid fever at St. Louis was due to the fact that typhoid germs did pass from the one city to the other. This opinion was given by the following experts:

Dr. Armand Ravold, for several years City Bacteriologist of St. Louis, and who had previous to his testifying studied bacteriology and sanitary science in the Universities of the United States and Europe.

George Chandler Whipple, the biologist and director of Mount Prospect Laboratory of the Department of Water Supply of the City of New York, and who likewise had given extensive study and scientific research to the various water supplies of the United States.

Gardner Stewart Williams, Professor of Experimental Hydraulics in Cornell University, who likewise had made a study of the life and conduct of water-borne diseases and of the various epidemics throughout the United States, and since appointed by the President of the United States as one of the consulting engineers in reference to the work of sanitation for the Panama Canal Zone.

Allen Hazen, a practical sanitary engineer of the City of New York, a graduate of the Thayers School of Civil Engineering at Hanover, the Massachusetts State Institute of Technology and the Technical School at Dresden, Germany. Mr. Hazen has

during his experience had charge of several experimental stations, the work of which was connected with purifying sewage and of sanitary problems. During the World's Columbian Exposition at Chicago he was in charge of the sewage disposal plant and of the inspection of the drinking water used on the grounds; he has made examinations of various water supplies throughout the United States and investigated many epidemics of typhoid fever with the view of determining the probable cause.

George W. Fuller, a practical sanitary engineer of New York, a graduate of the Massachusetts School of Technology and of the University of Berlin; a practical chemist, bacteriologist and sanitary engineer.

William T. Sedgwick, a Professor in the Massachusetts Institue of Technology, a member of the American Academy of Arts and Sciences, Massachusetts Associations Boards of Health, New England Waterworks Association, Society of American Bacteriologists, American Public Health Association, a member of the Advisory Board of Hygiene, Laboratory of the United States, member of the United States Public Health and Marine Hospital Service, president of the Society of American Bacteriologists, and is the author of a text-book on Biology and a treatise on the Principles of Sanitary Science and Public Health, and has made numerous examinations of and reports on typhoid fever epidemics throughout the United States. A large number of the experts of both the complainant and the defendants are pupils of Professor Sedgwick.

Dr. Herbert E. Smith, Dean of the Yale Medical School, a practical chemist and bacteriologist, having occupied a position on the State Board of Health of Connecticut for several years and examined many water supplies throughout the United States for the purpose of determining their sanitary qualities.

Prof. Edward P. Keiser, Professor of Chemistry to Washington University, with an extensive experience in the study of water supplies and the science of sanitation.

The opinion expressed by these experts was based upon actual experiments made in the laboratory and under natural conditions as to the longevity of the typhoid bacilli, and also as observed by them in the study of typhoid epidemics throughout the civilized world.

The opinion of these distinguished experts that the infected sewage of Chicago was the cause of the increase in typhoid fever in the city of St. Louis was also based upon the fact that in their opinions, after a full study of all the facts and a personal investigation of existing conditions, they were able to discover no other contributing cause to the increase in typhoid in St. Louis.

THAT PART OF THE SEWAGE OF CHICAGO WHICH PASSES THROUGH THE ILLINOIS AND MICHIGAN CANAL INTO THE ILLINOIS RIVER HAS NO IMPORTANT BEARING UPON THE ISSUES OF THIS CASE.

As considerable stress is laid by counsel for the defendants upon the fact that the Illinois and Michigan Canal has been used to a limited extent, for the same purpose as is the Chicago Drainage Canal, since 1836, the testimony of the complainant's witnesses in reference to the amount and character of the sewage of Chicago which comes through this canal into the Illinois river will be referred to.

The testimony shows that the greater part of the sewage of Chicago prior to the opening of the Chicago Drainage Canal, was discharged either into the Chicago river or directly into Lake Michigan. The small portion of the sewage of Chicago which emptied into the west fork of the south branch of the Chicago river was pumped thence into the Illinois Drainage Canal and from there flowed lazily into the Desplaines river and thence into the Illinois. But on account of the fact that both of these rivers were prior to the opening of the Chicago Drainage Canal sluggish, slow moving streams, the process of putrefaction was continued for such a length of time as to destroy the infectious material contained in such sewage. All of the witnesses agreed upon the point that such sewage as was discharged into the Desplaines and Illinois rivers through the Illinois and Michigan Canal prior to the opening of the Chicago Drainage Canal collected in large pools, in which septic action continued undisturbed and uninterrupted by the movements of those streams.

It is also shown clearly, both by the testimony of the witnesses for the defendants and the complainant, that by far the greater part of the sewage of Chicago that was pumped into the Illinois and Michigan Canal was that which came from the stock yards and packing house districts, in which districts there was but a limited population. This sewage, while offensive to the sight and smell, was free from those pathogenic bacteria destructive to human life which come from the thickly populated portions of the city.

It was also apparent from the testimony in the case that the construction of the Drainage Canal itself was necessitated by the fact that the sewage of the city of Chicago discharged into the Chicago river and into Lake Michigan was being pushed out into Lake Michigan and thus infecting the source of the water supply of that city. If any considerable portion of the sewage of Chicago had been or could have been carried to the Mississippi river through the Illinois and Michigan Canal, there would clearly have been no necessity for the construction of the Chicago Drainage Canal. The subject-matter of this law suit demonstrates the inconsequential part that the Illinois and Michigan Canal had in the law and the facts of this case.

CHEMICAL AND BACTERIOLOGICAL CONDITION OF THE WATERS OF THE MISSISSIPPI RIVER AT CHAIN OF ROCKS BEFORE AND AFTER THE OPENING OF THE CHICAGO DRAINAGE CANAL.

Another important fact, as disclosed by the testimony and which supports the theory of the complainant, was the testimony of the experts as to the chemical and bacteriological condition of the waters of the Mississippi river at the intake of the St. Louis waterworks before and after the opening of the Chicago Drainage Canal. It was the testimony of all the experts for the complainant, and practically conceded by the testimony of the experts for the defendants, that the failure to find pathogenic bacteria in a certain quantity of water, which might be made the subject of examination, was of no value or importance in determining the quality or potability of such water. It is, however, a well established fact, according to the testimony of those experienced in such sciences, that the chemical condition of water is of importance in that the presence of certain chemical properties indicates that the water is infected with sewage, while the absence of such properties would tend to show the contrary.

The chemical condition of the Illinois river at its mouth, and the Mississippi river at the Chain of Rocks, is shown to have been in a better sanitary condition, chemically speaking, prior to the opening of the Drainage Canal than subsequent thereto.

The chemical analyses introduced on behalf of the complainant show clearly the water of the Mississippi river at the Chain of Rocks became suddenly badly polluted the first week in February, 1900, and has since that date so continued to be highly

polluted from a chemical standpoint. This fact is shown by large increase in the quantity of free ammonia and nitrites in the reservoir water throughout the entire period from January 24, 1900, to 1903, as compared with the chemical condition of the water for a like period immediately prior thereto. The water of the Mississippi river above Grafton, the mouth of the Illinois and of the Missouri river, showing no real or substantial change since the opening of the Drainage Canal as compared with a similar period prior thereto, while the water of the Illinois river at its mouth is shown to have largely increased in chemical constitutents, such as free ammonia, albuminoid ammonia, nitrites and total solids in suspension since the opening of the canal as compared to conditions existing prior thereto.

There has, however, been a reduction in chlorines, as expressed in parts per million. This should be expected and is a verification of the statement that, chemically and bacteriologically speaking, the same degree of chemical reduction is not going on in the waters of the Illinois river since the opening of the canal as prior thereto for the reason that there has been an increase in all chemical constituents save chlorine. Chlorine is an indestructible soluble substance. Its quantity, therefore, is only affected by the extent of dilution to which it is subjected.

What has been said with reference to the chemical condition of the water at the Chain of Rocks since the opening of the Drainage Canal, as compared to a previous period, may also be said of its bacteriological condition as shown by the testimony of complainants.

The consequence is that the dilution caused by the added volume of water from Lake Michigan has had a decided preservative effect upon the chemical constituents and bacterial organisms contained in the waters of the Illinois river since the opening of the canal.

The total solids in suspension, free ammonia, albuminoid ammonia and chlorines, as a general proposition, are indications of sewage pollution when found in the chemical analysis of a water supply.

In determining the potability of a water supply, the observer takes into consideration the population residing upon the watershed, the character of the population and the volume of water contained in the stream. This constitutes a most important factor in passing judgment upon the character of the water, the chemical and bacterial observations being used simply as a name in determining the question as to whether or not the polluting material discharged into the river on account of the population above has become so far reduced as not to be of serious moment at the point where the water is being examined. Chemical analyses show the presence of objectionable material, or such material as is usually found in sewage polluted streams, but one cannot determine from a chemical analysis alone the exact fact that pathogenic bacteria or disease producing organisms are contained in the water. Nor can it be said that chemical analyses such as are made by chemists will determine the absence of such bacteria.

What is said with reference to the inability to make a correct determination of the potability of water by the science of chemistry is alike applicable to the science of bacteriology, it being necessary to connect the result of these observations with the physical condition of the water of the stream examined, such as the total population sewering into the river at points above it.

Taking into consideration the chemical and bacterial data obtained by complainant, as well as that of defendants, and applying the same to the recognized methods of sanitary scientists and engineers, it is but reasonable to expect that by the

addition of a population of two millions to the watershed of the Illinois river, the water of that river has become more thoroughly infected with disease producing bacteria, and that by the addition of 250,000 cubic feet per minute of water from Lake Michigan, the pathogenic bacteria, which constitute the infectious matter contained in the sewage, has become largely preserved over conditions existing prior to January 17, 1900.

The evidence shows that there has been an increase not only in volume, but in velocity as well throughout the entire length of the Illinois river, thus carrying the infectious matter rapidly from the city of Chicago to the mouth of the Illinois river, and also conveying more rapidly the infectious material that is deposited in the river at various points along its course.

SCIENTIFIC INVESTIGATIONS AS TO DURATION OF LIFE OF TYPHOID BACTERIA IN A RUNNING STREAM.

Complainant's witnesses, in expressing an opinion as to the ability of pathogenic bacteria to pass from Chicago to St. Louis, voiced the practical experience of their profession with reference to the longevity of typhoid bacilli in a sewage polluted stream. The limit of longevity in such a stream has always been fixed at not less than twenty-five days, and bacteriologists and scientists have not as yet been willing to express it as their opinion that even at the expiration of such a period all of the typhoid germs discharged into the water will have perished.

Dr. Hiram F. Mills of the Massachusetts State Board of Health made a series of tests along this line, and found them to live with gradually reducing numbers from one to twenty-five days in the waters of the Meramec river, which is known to be more highly polluted than the waters of the Drainage Canal. The evidence of defendants, in fact, substantiates the experience of sanitarians upon this subject.

Professor Mason, one of defendants' witnesses, admitting that in his opinion the more resistant organisms would pass from Chicago to St. Louis.

Mr. Herring, also for defendants, stated that throughout his experience as a sanitary engineer, in passing upon the longevity of typhoid fever germs as applicable to a water supply, he had invariably used the table prepared by Dr. H. F. Mills, and that in all of his experience he had known of no instance where it was believed by sanitarians that typhoid germs had disappeared from a sewage polluted stream within a shorter time than from fifteen to twenty-five days.

Dr. Barker, one of defendant's experts, stated that he would not say how long these germs would live in the waters of the Illinois river, or in any river; that sufficient had not been learned to express a reliable opinion.

Professors Long and Palmer (both for the defense) stated that according to the science of chemistry, there was no known way of determining the presence of pathogenic bacteria in the samples of water examined, and that as to the chemical substances found in the waters of the Illinois river at its mouth, which are usually considered to be evidence of sewage pollution, they were unable to say that such constituents did not contain infectious germs.

Professor Jourdan, Professor Zeit, Professor Russell and Professor E. G. Smith, all of whom likewise testified for the defendants, admitted that the longevity of typhoid germs in a running stream is unknown; that so many favorable elements to the life of the germ during their passage down a stream enter into the question of longevity, that no one could speak with absolute certainty as to the exact duration of life. Also, that each germ represented a life within itself and is possessed of certain powers of vitality stronger perhaps than its associates, enabling it to survive a longer journey than its less strong kindred companion.

The foregoing statement of fact constitutes in a concrete and succinct form the facts which make complainant's case.

DEFENDANTS' TESTIMONY.

The statement of facts above made is seriously disputed by the defendants only upon two propositions, which are to be considered important:

First: It is contended that infectious material discharged in the canal at Chicago will not reach the city of St. Louis in such condition as to produce a bad effect upon the people of that city using the water of the Mississippi river for domestic purposes.

Second: That there has been no increase in typhoid fever in St. Louis since the opening of the Drainage Canal, as compared with conditions prior thereto.

Upon the first proposition, defendants are compelled to rely upon what may practically be stated the unsupported expert opinions of Professor Jourdan, Professor Zeit, Professor Russell, Professor E. G. Smith, Professor Mason, Professor Kennicut and John W. Hill.

The opinions expressed by the above witnesses are at total variance with the experience of the science of sanitation throughout the world, and contrary to the general belief of persons supposed to know; in fact, contrary to the former experience, opinions and belief of the witnesses themselves.

After defendant had commenced the taking of testimony, a series of experiments were carried on in its behalf by Professor Jourdan, Dr. Zeit and Professor Russell. These experiments were conducted by means of depositing typhoid infected Illinois river, Drainage Canal and Lake Michigan water in parchment sacs and suspending the sacs in the running stream, or in the body of the lake. From day to day samples of the contents of these sacs were removed and analyzed for the pur-

pose of observing, if possible, the presence of typhoid fever germs. The experiments show no difficulty in observing their presence as long as three days, a few instances longer, and in one instance three colonies of typhoid bacteria were removed at the end of the tenth day.

The above experiment was made without the knowledge of complainant, and in such manner as does not conform to the actual conditions existing in the running stream. In fact, the same objections are apparent to these experiments as have been advanced against laboratory experiments, and their failure to represent the conditions actually existing in water in its natural condition.

Professor Russell admitted that there were many reasons why these experiments did not conform to the natural conditions of the stream; Professor Jourdan and Dr. Zeit joining in the above statement, with the proviso that natural conditions were obtained as near as possible. This experiment persuaded defendants' experts to express opinions to the effect that pathogenic bacteria, such as typhoid, coming from the sewers of Chicago, perish in the Illinois river before St. Louis is reached.

In opposition to complainant's proof of the increase in typhoid fever in St. Louis, defendants saw proper to introduce in evidence the published health reports of the city concerning the number of deaths occurring from malaria, intermittent, remittent, typho-malaria, typho-pneumonia, congestive, continued and enteric fevers. This was done for the ostensible purpose of showing that a great many deaths reported as occurring from these diseases were in reality typhoid and should have been reported as such. Objection was made by complainant at the time of the introduction of this testimony, because the tabulated table or column setting forth the intermittent, remittent,

malaria, etc., contained deaths occurring from diseases other than typhoid or intermittent, remittent, etc., that had been carried into it by the person compiling the report, and for that reason the evidence was too unreliable and uncertain to show the number of cases that had been reported as malaria, intermittent, remittent, etc., by the physicians of the city.

Defendants' evidence was to the effect that about fifty per cent of the deaths recorded as intermittent, remittent, etc., should be carried into the typhoid column, because they were in reality deaths due to typhoid.

Admitting the admissibility of the evidence and the correctness of the statements of defendants' witnesses in the above connection, the result nevertheless is that there has been an increase in the number of deaths from typhoid in the city of St. Louis since the opening of the Drainage Canal. Such increase has been gradual and not spasmodic or occurring at intervals; showing the cause or source to be a permanent impairment of the water supply.

No attempt was made by defendants to show or in any way explain the increase in typhoid fever in St. Louis than as above set forth.

The data setting forth the deaths from typhoid fever in the principal towns and cities of the respective watersheds, introduced by complainant, was, after being verified by defendants, agreed upon and adopted.

No attempt was made to show that wells and milk contributed to the increase, save the opinion of some of defendants' witnesses expressed without being supported by sufficient facts.

Defendants also introduced chemical and bacterial data for the purpose of showing that the water of the Illinois river carried with it less infectious and polluting material since the opening of the canal than prior thereto. This testimony shows a

slight reduction in chemical substances and bacterial counts. The reduction in chlorines since the opening of the Drainage Canal has largely corresponded with the increased volume of water passing down the river from Lake Michigan.

The chemical data introduced by defendants, however, does not show the same degree of reduction in chemical substances, other than chlorine, which should be produced by reason of the diluting effect of the lake water upon the water of the river.

The reduction of total organic nitrogen in the Illinois river at Kampsville, near its mouth, as shown by defendants' evidence, is only 17.48 parts per million, while, according to the reduction in chlorines and the added volume of water, it should be 50 per cent. Defendants, in their statement of the case, conceding that the added volume of water from Lake Michigan equaled, and at times exceeded, the volume of water originally passing down the river.

Dissolved oxygen, according to defendants' testimony, decreases but 17.92 per cent at Kampsville, when the reduction should have been not less than 50 per cent.

Free ammonia, instead of being reduced, shows an increase of six per cent since the opening of the Drainage Canal, as compared with conditions prior thereto. Of all the chemical constituents contained in water, it may be said that free ammonia, accompanied with nitrites and chlorine, constitutes the best evidence of recent pollution from a strictly chemical standpoint.

Defendants, over the objection of complainant, introduced the testimony of experts to the effect that it would be necessary for the city of St. Louis to construct a filtration plant in order to secure a good, wholesome water supply, and that in the construction and operation of such a plant there would be no increase in cost on account of the infectious material contained in the water of the Mississippi river received from the sewage of Chicago.

COMPLAINANT'S REBUTTAL TESTIMONY.

In rebuttal, complainant introduced proof showing the actual number of deaths in St. Louis from typhoid fever, intermittent, remittent, malaria and kindred diseases for the years 1896 to 1903, inclusive, as reported by the local physicians and the coroner to the Health Department, and as recorded in the books of the mortuary office of the Health Department of the city. This was introduced for the purpose of refuting whatever statement of fact may have been introduced on behalf of defendants affecting the reliableness of the published Board of Health reports upon deaths from malaria, intermittent, remittent, etc., and their being recorded in the reports as such when in reality the true cause of deaths was typhoid fever. This testimony shows that while throughout the entire period there have been a great many deaths in St. Louis reported as caused by intermittent, remittent, malaria fever, etc., yet the number so reported has been practically the same throughout the entire period, and that there was no falling off in such reported deaths during the years 1900, 1901, 1902 and 1903, as was attempted to be shown by defendants.

This testimony further shows that, by adding together for each year all of the deaths reported from typhoid and those reported as intermittent, remittent, malaria fever, etc., there has been an increase in deaths from typhoid of about 77 per cent for the years 1900, 1901, 1902 and 1903 as compared with the years 1896, 1897, 1898 and 1899, inclusive.

Defendants made no attempt to disprove the accuracy of this proof; their counsel seeing proper to rest upon the simple objection as to its admissibility.

Complainant also offered in rebuttal evidence showing that the cost of constructing and operating a filtration plant at St. Louis would necessarily be more expensive on account of the infectious material possessed by it that is derived from the sewage of Chicago, than if such infectious material had been eliminated from the water before its discharge into the canal at Chicago.

In the above connection, complainant also offered in evidence testimony showing that it was practicable for defendants to construct a sewage treating plant at Chicago sufficient to treat the entire sewage disposal of that city, so as to render the same innocuous, as is now being done in other cities, notably Berlin, Paris, Munich, etc.; and that it was also practicable and feasible for the city of Chicago to construct a water filtration plant which would purify the water of Lake Michigan at the same time, even if the sewage of Chicago was discharged into the Chicago river and Lake Michigan the natural depository for it.

The foregoing constitutes a brief summary or statement of the facts shown in evidence.

CONCEDED FACTS.

The following propositions can be stated as practically conceded both on behalf of complainant and defendants:

1st. That infectious material is discharged into the Drainage Canal at Chicago and flows down the canal the Desplaines and Illinois river, and is discharged into the Mississippi at Grafton.

2nd. That pathogenic bacteria live in the waters of a running stream, the exact time being as yet undetermined; there being no way by which the exact longevity of such germs under the variable conditions in a river can be tested.

3rd. That dilution tends to prolong the life of pathogenic bacteria and preserves their virulence.

4th. That typhoid fever is what is known by sanitarians as a water-borne disease, and is caused by the use of typhoid infected water for domestic purposes.

5th. That all things considered, the greater the population residing upon a given watershed, the more unsafe and unsuitable becomes the water of that stream for domestic purposes.

6th. That the chemical and bacteriological condition of water is of value and of importance as tending to show the existence or non-existence of pathogenic producing bacteria.

With these propositions practically conceded by the witnesses who testified in behalf of the complainant and defendants, the principal issues of fact which remain as questions of difference in the case are:

First: Whether there has been or has not been an increase in typhoid fever in the city of St. Louis after the opening of the Chicago Drainage Canal on January 17, 1900.

Second: Conceding that there has been an increase in typhoid fever in the city of St. Louis after the opening of the Chicago Drainage Canal, is such increase due to the infection of the water supply of St. Louis by reason of the sewage of Chicago discharged in the Drainage Canal?

Third: Do typhoid fever bacteria contained in the sewage of Chicago retain their life and virulence until the water in which they are contained is used by the people of St. Louis for domestic purposes?

Fourth: As to whether there is any other cause for the increase in typhoid fever in St. Louis other than the discharge of typhoid infected sewage into the water supply of St. Louis by the use of the Chicago Drainage Canal.

POINTS AND AUTHORITIES.

We herewith submit the following points and authorities in reply to the propositions of law and fact involved in defendants' brief and argument, and defendants' reply to brief and argument of complainant:

I.

Complainant is not estopped by the doctrine of laches.

Wood on Nuisances, Sec. 806.
Mills vs. Hall, 9 Wend. l. c., 316.
Commonwealth vs. Upton, 6 Gray, 473.
Attorney-General vs. Copper Co., 152 Mass., 452.
State vs. Rankin, 3 S. C., 448.
New Salem vs. Eagle Mills, 136 Mass., 8.
Burke vs. People, 23 Ill., 36.
Gould on Waterways, 3 Ed., Sec. 121.
Gould on Waterways, 3 Ed., Secs. 212 and 523.
City of Waterloo vs. Union Mill Co., 72 Ia., 438.
Rhodes vs. Whiteridge, 27 Tex., 304.
Jersey City vs. Canal Co., 12 N. J. Eq., 348.
Dygart vs. Schenk, 23 Wend., 436.
Welch vs. Hornby, 7 East, 199.

II.

Complainant's right to maintain this action is complete. Complainant is not guilty of lack of due diligence.

The cases cited by defendants to the effect that complainant's right to maintain this action has been lost because of lack of due diligence on its part are not in point, as will be noticed from an examination of them as set forth in our argument under this sub-division.

The point here involved is kindred to that set forth under Point I hereof. The authorities there cited are applicable here.

III.

The court will not undertake to balance the conveniences suffered by the parties. If complainant is damaged relief will be granted.

Attorney-General vs. Hackney, 20 L. R., Equity, 626.
Indianapolis Waterworks Co. vs. American Strawboard Co., 53 Fed. Rep., 970.
Lewis vs. Staein, 30 Am. Dec., 179.
Dwight vs. Hayes, 150 Ill., 273.
Spence vs. McDonough, 77 Ia., 460.
Ferguson vs. Mfg. Co., 77 Ia., 576.
Harris vs. McIntosh, 133 Mass., 228.
Anderson vs. Henderson, 124 Ill., 164.
Dayton vs. Drainage Commissioners, 128 Ill., 271.
Jackman vs. Arlington, 137 Mass., 277.

While in some cases the court will measure the conveniences between the parties, it will not be done in suits of this sort.

When a water supply is being burdened with an unnecessary use, courts will not attempt to balance the conveniences between the parties, but will preserve the water in its natural condition, as near as possible, for the benefit of those who are compelled to use it.

Courts will not undertake to balance conveniences so long as there is a practical way of avoiding the injury complained of by compelling defendants to keep within due bonds, or to so change his conduct as to free complainant from all injury. Especially is this true:

1st. When the life, health and comfort of the people constitute the basis of the injury complained of.

2nd. When defendant attempts to disturb natural conditions and natural laws, as by attempting to force its waste materials, sewage and filth upon the people residing upon an adjoining watershed, thereby subjecting them to unnatural conditions.

3rd. When it is shown that it is entirely practical for defendant to treat its sewage so as to remove from it the deleterious and objectionable substances before its discharge into the canal.

4th. When defendant, by filtering its own water, could still allow the sewage from Chicago to flow into Lake Michigan, the natural drainage basin of that city.

5th. When defendant could treat its sewage at Chicago and permit the effluent thereof to be discharged into the lake, without injury to its water supply.

Equity will not refuse to protect one in the possession and enjoyment of his property merely because his right is less valuable to him than the power to destroy it may be to another or the public.

Sullivan vs. Steel Co., 208 Pa., 540.

IV.

The fact that certain municipalities in the State of Missouri discharge sewage into the Missouri and Mississippi rivers does not justify the city of Chicago in discharging its sewage into

the canal, thereby forcing it upon the people of the Mississippi valley, and burdening them with an inconvenience not intended by nature.

Am. & Eng. Enc. of Law, 2nd Ed., Vol. 30, p. 408.
See also Complainant's Original Brief, under title "Contribution and Exoneration."

V.

The evidence of witness E. E. Lockridge, who testified for complainant as to the contents of the records in the mortuary office of the city of St. Louis, is admissible.

Renner vs. Bank of Columbia, 22 U. S., 581.
U. S. vs. Reburn, 31 U. S., 350.
Clark vs. Hornbeck, 17 N. J. Eq., 430.
Wigmore on Evidence, Sec. 1230.

Where a fact can be ascertained only by the inspection of a large number of documents, made up of numerous detail statements, the principle requiring the production of such documents, for the purpose of obtaining evidence of their contents, does not apply. In such cases, for the convenience of the court, evidence is allowed in the shape of testimony of a competent witness who has perused the entire document or mass of detail statements, he being permitted to state summarily the net result.

Wigmore on Evidence, Vol. 2, Sec. 1230.
San Pedro Land Co. vs. Reynolds, 121 Cal., 74.

VI.

In order to authorize the injunction sought, the act complained of need only be shown by satisfactory evidence. All

that is necessary is that complainant make out a clear case, showing the injury inflicted or the injury impending and about to fall. With such showing relief is always granted.

Lambert vs. Lewinski, 47 Ill., 656.
Owen vs. Phillips, 73 Ind., 284.
Mirkle vs. Morgan, 134 Pa. St., 144.
Halsman vs. Boiling Spring, 14 N. J. Eq., 335.
Rowell vs. Bentley, 34 W. Va., 804.
Niginer vs. Norwood, 72 Ala., 277.
Hamilton vs. Whitehead, 11 Md., 128.
Bates vs. Elmira, 22 Hun., 158.

VII.

The opinion of lay witnesses as to the value of the water should be excluded. Witnesses should not be permitted to speak unless they know, nor should they be permitted to make damaging statements unless they be in a position to speak with certainty as to the truthfulness of the facts stated, or be sufficiently skilled to form some reliable opinion.

Wigmore on Evidence, Secs. 1917 and 1924.

The witnesses residing upon the banks of the Illinois river, a large number of whom were fishermen by occupation, were in no sense experts, had no knowledge of sanitary science, and could not judge of the sanitary condition of the water of the river. Not being experts, it is improper for their testimony to be considered, so far as it affects matters requiring special knowledge not possessed by them.

Shaw vs. Boom Co., 125 Pa. St., 324.
State vs. Punshaw, 133 Mo., 55.

Pfau vs. Alteria, 52 N. Y. Sup., 88.
R. R. Co., vs. Bruce, 17 S. W., 363.

VIII.

While municipal authorities have power to construct and maintain sewerage systems for the health and comfort of the inhabitants and may discharge the same into the navigable streams and waters, yet the right to discharge the same into such streams does not exist to the extent of creating a nuisance, or to inflicting an injury upon lower riparian owners.

(See authorities cited in plaintiff's original brief.)

Although a municipality may, within reasonable bounds, discharge sewage into a stream upon which it is situated, the right so to do has emanated from what has been termed the law of necessity, and this law has not yet been so construed as to permit those having no interest whatever in the preservation of the waters of a stream to disturb natural conditions at will.

(See authorities cited in Complainant's original brief.)

IX.

The Acts of Congress of 1822 and 1827, authorizing the State of Illinois to construct a canal connecting the waters of Lake Michigan and the waters of the Illinois river, do not justify defendants in discharging the sewage of the city of Chicago into the Illinois river, and thence into the Mississippi river.

X.

The evidence establishes affirmatively the following propositions:

1st. Typhoid fever germs enter the sewers of Chicago and survive the journey to St. Louis in a virulent condition, causing typhoid fever among the inhabitants of St. Louis.

2nd. Since the opening of the drainage canal there has been an increase in typhoid deaths in St. Louis of 77 per cent, as compared with a like period of time immediately prior to said opening.

3rd. No local cause or infection is shown to have existed which accounts for such increase.

4th. The increase in typhoid deaths in St. Louis since the opening of the drainage canal has not been caused by sewage discharges into the Missouri, Mississippi or Illinois river, exclusive of the city of Chicago, the evidence showing no increase in typhoid deaths in the principal cities located upon the watersheds of the respective rivers since January 17, 1900.

5th. The evidence shows the increase of typhoid fever deaths in St. Louis to have been gradual, continuous and of a permanent character, there being no evidence of spasmodic conditions such as might be expected from an epidemic at some point above, thus authorizing the deduction that the source of the infection was continuous and of a character such as the large and populous city of Chicago would produce.

6th. The opening of the drainage canal on January 17, 1900, and its operation since that date, constitute a danger and a menace to the inhabitants of the State of Missouri compelled by necessity to use the water of the Mississippi river for domestic purposes, such danger and menace being at all times present, permanent and impending.

7th. That prior to the opening of the Drainage Canal on January 17, 1900, the city of St. Louis was possessed of a reasonably safe water supply, equal to that of Boston, which is recognized as being above the average.

8th. That since January 17, 1900, the water supply of St. Louis has been decidedly typhoid infected and of an unsafe and dangerous character. This, too, although there has been no change in the manner of its treatment, and no such change of conditions on the watershed of the Mississippi, exclusive of the opening and operation of the Chicago Canal, that can in any way be said to constitute the cause of the unsafe condition.

XI.

The injury to complainant is such that, in order to reduce the typhoid mortality in St. Louis to the limitations existing prior to the opening of the canal, defendants must be restrained from discharging the sewage of Chicago into the canal, or a water filtration plant must be erected at St. Louis. The cost of building and operating such plant would be materially increased because of having to deal with the effect of Chicago sewage upon the waters of the Mississippi river.

XII.

Even though there should be a time when, under natural conditions, the city of St. Louis would be required to construct a filtration plant for the purpose of preserving the health of its inhabitants, the city of Chicago is possessed of no right to contribute to the conditions which would bring about such requirement.

ARGUMENT OF LAW AND FACTS.

In reply to defendants' briefs we shall first consider the questions of law presented. By reason of the fact that defendants have presented their side of the case in two briefs, it is necessary, in making this reply, that distinct reference be made to them. Their two briefs are designated by them as "Brief and Argument on behalf of Defendants," and "Reply of Defendants to Brief and Argument of Complainant." We shall, therefore, designate them as "Defendants' Brief and Argument," and "Defendants' Reply Brief and Argument," respectively.

I.

COMPLAINANT IS NOT ESTOPPED BY LACHES.

The first proposition presented in Defendants' Brief and Argument (Part II thereof) is that because in the prosecution of the work of the Chicago Drainage Canal by the defendant, Sanitary District of Chicago, at an expenditure of over $42,500,000, complainant had knowledge of this great public improvement, and has stood by in silence, and acquiesced, impliedly, in its construction, and is, therefore, estopped by the doctrine of laches.

It will be remembered by the court that when this case was presented upon the demurrer to complainant's bill, it was insisted upon by defendants that complainant had prematurely instituted the proceedings, and that if it was not prematurely in-

stituted it was then too late to be filed, for the reason that the State of Missouri has stood by for so long a period during the construction of the canal as to be guilty of such laches as would prevent the court's granting the relief sought. In commenting upon this contention, the court said:

> "The inconsistency between these contentions is manifest, and on consideration we are of the opinion that the suggestion that complainant's remedy has been lost by delay is not founded in fact or reason."

While it is true a party in some cases may by laches deprive himself of an equitable remedy against a nuisance by sleeping upon his rights and allowing the nuisance to go on without remonstrance, or, rather, without taking measures, either by a suit at law or in equity, to protect his rights, he will be regarded as guilty of such laches as to deprive him of equitable relief; but such authority as has been cited by defendants is not applicable to the case at bar.

Several citations from Wood on Nuisances are set forth in defendants' brief and argument to the above effect. But before it can be determined that complainant is estopped from instituting the proceedings in question, or that by its laches it has deprived itself of equitable relief, it must first be held that complainant has acquiesced in all that has been done looking towards the establishment and continuation of the nuisance. Wood on Nuisances, section 806, in this connection, says:

> "As to what constitutes an acquiescence in a nuisance, to the extent to deprive a person of equitable relief, as well as to constitute an equitable estoppel, so that a court of equity will restrain a party from proceeding at law to recover damages arising from a nuisance, it may be said that mere delay for several years in bringing an action will not of itself constitute

an acquiescence. Neither will an actual assent to the erection of the nuisance, and active participation in its erection, unless the party had reason to suppose that the erection would be a nuisance. But if the thing or erection is, of itself, or in the use to which it is to be devoted, in its nature a nuisance, assent thereto or active acquiescence therein is such an acquiescence as will deprive a party of an equitable remedy, *and after the erection is completed, and by its use has become a nuisance, if the party, without taking measures to stop the nuisance by suit, allows the owner to go on and make large additions thereto, or expend money upon the same in its repair, this will operate as an equitable estoppel which will warrant a court of equity in restraining proceedings at law for damages arising from the nuisance. But in order to constitute such estoppel there must be 'wrong on one side and freedom from blame on the other.'* • • • If the thing was something which might or might not become a nuisance, according to the circumstances of its use he would not be estopped unless he knew the precise methods of its use, and was fairly chargeable with notice of its results."

In this connection we call the court's attention to the fact that this bill was filed the day the drainage canal was opened. So that applying the doctrine above laid down that "after the erection is completed and by its use has become a nuisance, if the party, without taking measures to stop the nuisance by suit, allows the owner to go on and make large additions thereto, or expend money upon the same in its repair," he will be estopped, and such conduct upon his part will warrant the court to estop

him in any action he may bring for injury of which he may complain.

In this case the bill was filed as soon as the canal was completed and before any injury or damage had been done.

Then, too, it must be said from the foregoing citation that complainant had no right to assume by the construction of the canal in question connecting Lake Michigan with the Mississippi river that the city of Chicago would discharge its sewage into the canal in an unpurified condition. The converse is true. Complainant had the right to assume that inasmuch as the city of Chicago had no natural right to convey its sewage from the watershed of Lake Michigan to that of the Mississippi river that before such discharge was made into the canal its sewage would be subjected to some course of treatment so as to remove the objectionable and deleterious substances from it.

In our original brief we called the court's attention to the fact that under the law defendants have no right by prescription to continue a public nuisance, nor can the right to maintain or continue a public nuisance be acquired by prescription. With this principle of law applicable to the present case, all those decisions based upon the question of equitable estoppel or laches must be held to be inapplicable, for the reason that they apply more generally to questions affecting private nuisances rather than those of public concern.

In the case of Mills vs. Hall, 9 Wend., l. c. 316, it was held that there is no such thing as a prescriptive right or any other right to maintain a public nuisance, and although defendant's dam may have been located and maintained for more than twenty years, and that during the whole of that period it had rendered the adjacent country unhealthy, such length of time can be no defense to a proceeding on the part of the public to

abate it, or to an action by any individual for the special and pecaliar injury which he may have suffered from it."

Commonwealth vs. Upton, 6 Gray, 473.
Attorney-General vs. Copper Co., 152 Mass., 452.
State vs. Rankin, 3 S. C., 448.
Chitty on Criminal Law, Vol. I, 190.
New Salem vs. Eagle Mills, 136 Mass., 8.
Burke vs. People, 23 Ill., 36.
Hoadley vs. People, 23 Ill., 39.
Gould on Waterways, 3 Ed., Sec. 121, p. 236.
Gould on Waterways, 3d Ed., Sec. 212.

Gould on Waterways, Sec. 532, lays down this doctrine: "Since laches or acquiescence in the defendant's act for less than a prescriptive period may defeat the plaintiff's right to an injunction a *fortiori*, adverse possession and exercise of any right in water in derogation of the rights of other owners for twenty years, or for a period sufficient to establish a prescriptive right, necessarily defeats the right of such owners to an injunction against a private nuisance. IN THE CASE OF A PUBLIC NUISANCE, HOWEVER, THE RIGHT OF THE PUBLIC IS, UPON PRINCIPLE, NEVER BARRED. ONE CAN NOT ACQUIRE A PRESCRIPTIVE RIGHT TO MAINTAIN A PUBLIC NUISANCE, AND NO PRESCRIPTION WILL DEPRIVE THE PUBLIC OF THE REMEDIES AGAINST SUCH AN INJURY."

In the case of Cross vs. Morristown, 18 N. J. Eq., the court adopted the language of Commonwealth vs. Upton, 6 Gray, 476, as follows: "*It is a positive rule of law, as reasonable as it is firmly established, that no length of time will legitimate a nuisance, or enable a party to prescribe for its continuance.*"

The same principle is put in force in

Mills vs. Hall, 9 Wend., 315.
People vs. Cunningham, 1 Denio, 636.
City of Waterloo vs. Union Mill Co., 72 Ia., 438.
Rhodes vs. Whitehead, 27 Tex., 304.
Jersey City vs. Canal Co., 12 N. J. Eq., 548.
Dygart vs. Schenck, 23 Wend., 446.
Weld vs. Hornby, 7 East, 199.

Defendants refer to the case of Attorney-General vs. Bradford Canal, and Attorney-General vs. Sheffield Gas Consumers Co., referred to by Gould in his work on Waters, 3d Ed., Sec. 533, in which it is said, "That delay will affect the attorney-general as much as a private individual. I am not prepared to say, but in my opinion it is a circumstance to be considered in determining the question whether this court shall interfere, although the application to the court be on behalf of the attorney-general. But I ground myself in that opinion upon what fell from Lord Eldon, in the case of Attorney-General vs. Johnson, wherein it was said, 'If the King's subjects have permitted the erection of a building which they were aware would, when completed, be a nuisance, without promptly applying to the court to prevent it, the court would not consider them entitled to the extraordinary assistance of a court of equity, but leave them to their legal remedy.' "

In discussing the proper construction to be placed on the foregoing language of the court, Gould says: "Neglect on the part of the public may create such equitable estoppel as to lead courts of equity to decline to exert the extraordinary remedy of injunction in its behalf. *Such neglect is not in any sense a bar of the right of the public*, but is a circumstance to be considered by the court with other circumstances in determining whether

the conduct of the complainant justifies interference by equity." As applicable to the case at bar it will be observed that complainant, as heretofore stated, had no sufficient knowledge to justify the institution of proceedings prior to January 17, 1900, for the reason that it had every right to presume that defendants would operate the canal without discharging unpurified sewage of the city of Chicago into it.

In addition, the court declared itself, when passing upon the demurrer to the bill, wherein, as heretofore stated, the two points were raised, first, that the bill was prematurely filed, and second, if not prematurely filed, that complainant had slept upon its rights, and therefore the doctrine of estoppel would apply. The most that can be said of the cases referred to by defendants is that such long continued use may be used simply as a circumstance, but in nowise are they controlling; nor has there been any change in the general proposition that the right to continue a public nuisance can not be established by prescription, or long continued acquiescence. In other words, the doctrine of estoppel does not apply as against a public.

Applying the doctrine laid down in the case of Attorney-General vs. Johnson, *supra*, to the case at bar, which is relied upon by defendants, there is no reason why the alleged short delay on the part of complainant to institute this proceeding should operate as a stay of its right to proceed, or prevent it from recovering as prayed. While it may be true that in some cases the facts may be such as to warrant a court in considering them along with other reasons why the suit should not be maintained, yet in this case we have a rapidly growing city of over two millions population, with practically its entire sewage disposal discharged into the drainage canal, and into the Illinois and thence into the Mississippi river from and after January 17, 1900. This fact, considered together with the attack

made upon the bill by defendants because it was filed prematurely, in our judgment, renders the principle referred to in the Johnson case inapplicable.

We, however, rely in full confidence upon the numerous decisions heretofore referred to, which hold that the doctrine of estoppel, laches and obtaining the right to perpetuate and continue a nuisance on the ground of long continued usage, does not run as against the public.

II.

COMPLAINANT'S RIGHT TO MAINTAIN THE ACTION IS COMPLETE. IT IS NOT GUILTY OF LACK OF DUE DILIGENCE.

The second proposition discussed by respondents in their brief and argument is: "It is a well established doctrine of the Supreme Court of the United States that laches on the part of complainant is a bar to the granting of equitable relief. This is especially so where the lack of diligence on the part of the complainant has led the defendant to place himself in a position from which he can not escape or recede without great loss and inconvenience.

"The question of laches does not depend, as does the statute of limitation, upon the fact that certain definite time has elapsed since the cause of action occurred, but whether, under all the circumstances in the particular cause, complainant is charged with the one of due diligence in failing to institute proceedings before he did."

In support of this proposition a large number of cases are referred to, none of which can have any bearing upon the questions involved here.

We refer, briefly, to the cases cited by defendants in this connection, for the purpose of showing that they have no application to the question now under consideration:

McKnight vs. Taylor, 1 Howard, 168, was a case involving private rights of a creditor against a debtor. It appeared that nineteen years and three months had elapsed before any application was made for relief by the plaintiff. No reason was assigned for the delay, nor was it alleged to have been occasioned

in any degree by obstacles thrown in the way by defendant. As the record stands it seemed to have been the result of mere negligence and laches. The property in question was real estate situated in the town of Alexandria, Va., and could have been sold upon the application of any creditor as soon as default was made in the payment of the debt, without asking the intervention of a court of equity. The court said: "Such delay, under such circumstances, by the original creditor, followed by fourteen years more by the assignees, who afterwards had charge of the claim, can perhaps hardly be accounted for without supposing that the debt had been nearly, if not altogether satisfied. Indeed, if the suit had been postponed a few months longer twenty years would have expired, and in that case, according to the whole current of authorities, the debts in the schedule would have been presumed to be paid."

This was a matter of accounts between two parties. The court very properly held that while they may not be barred by the act of limitations, yet equity refuses to interfere after a considerable lapse of time, from considerations of public policy, and from the difficulty of doing entire justice when the original transactions had been obscured by time, and the evidence may be lost. In the case at bar there is no such difficulty arising as would prevent a full consideration of all the facts involved, nor has any evidence become lost or destroyed.

In Badger vs. Badger, 2 Wallace, 87, the bill alleged fraud, which had been practiced upon plaintiff many years prior to the institution of the suit.

Reading from the case of Michaud vs. Girod, 4 Howard, 503, the court said: "The facts of the case were clearly established by records other than written documents, and the court was not called upon to found its decree on the failed memory or active imagination of ancient witnesses who were not able, after

the lapse of time, to distinguish between their faith and their knowledge, between things seen or heard by themselves or those received from family or neighborhood gossip, or upon that most unsafe of all testimony, conversations or confessions remembered or imagined, partially stated or wholly misrepresented."

From the foregoing decision the reason for the rule laid down by the authorities cited by defendants becomes manifest. No such principle is involved here.

The case of Twin Lick Oil Co. vs. Marbury, 91 U. S., 587, is a case involving private rights affecting corporate property. For the same reason heretofore enunciated the court properly held the doctrine of laches to apply.

In Harwood vs. National Bank, 96 U. S. 611, it appears that the plaintiff borrowed of defendant money on call, and deposited with it as collateral security certain mining stock, with written authority to sell it at its discretion. The loan remained unpaid until the bank notified him that unless it was paid the stock would be sold. He failed after repeated demands, and the stock was sold for more than its market value to three of the directors of the bank, and the proceeds applied to the payment of the debt. Plaintiff was afterwards advised of the sale, and that enough had been realized to pay the indebtedness. To this he made no objections. Nearly four years after the sale, the stock in the meantime having greatly increased in value, plaintiff notified the bank of his desire and purpose to redeem, and subsequently filed his claim against it, asserting his right so to redeem. It was properly held that he was not entitled to the relief sought. This case has no bearing upon the one at bar.

In Harwood vs. R. R. Co., 17 Wall., 78, the bill was filed by a third party to set aside fraudulent completed judicial proceedings regular on their face. It was found that plaintiffs had slept upon their knowledge of the frauds committed upon them

for several years, and without reference to any statute of limitations the court, of course, adopted the principle that the delay was sufficient to invoke the doctrine of laches.

It appears from the decision of the courts in the foregoing cases that defendants are relying upon the well known doctrine of estoppel and laches as applicable to cases of fraud and general equity cases involving property rights of persons in private civil transactions. This principle has been long established by equity courts. The remaining cases cited by defendants in this connection throw no new light upon the proposition. While the principle enunciated in those cases has become established law of the land, it is also true that where public rights are involved, or where the public is in any wise concerned with reference to the establishment of a nuisance, the right can not become permanent by prescription, sufferance, limitation or laches. We submit that there is nothing, either in the pleadings or in the evidence in this cause, under all the circumstances surrounding it, to justify the court in changing its view: first, that this cause was not prematurely instituted; and, secondly, that the doctrine of laches can not now be invoked by defendants.

III.

THE COURT WILL NOT UNDERTAKE TO BALANCE THE INCONVENIENCES SUFFERED BY THE PARTIES. IF COMPLAINANT IS DAMAGED RELIEF WILL BE GRANTED.

Defendants take the position that the court should refuse to grant an injunction in the case at bar in that it appears that greater injury and inconvenience will be caused to defendant by the granting of the injunction than will be caused to complainant by refusing it. In this connection defendants say:

> "In deciding the case at bar the court should and undoubtedly will take into consideration whether or not the granting of the injunction prayed for will not cause greater damage, injury and inconvenience to the defendants than a refusal to grant the injunction will cause to the complainant. In cases of this kind this question is always balanced, and the injunction will not be granted where it will be productive of greater injury than will result from the refusal of it."

Counsel for defendants are mistaken in the application of the doctrine announced. The injunction sought in this case is for the purpose of protecting the lives and health of complainant's inhabitants. The evidence shows a great increase in the death rate from typhoid fever in complainant's metropolis, to wit, St. Louis, since the opening of defendants' canal. As stated in our original brief, the damage to complainant can scarcely be calculated, both from the standpoint of public health, public convenience, public safety, or from a pecuniary standpoint. In fact, as shown by the evidence, the injury inflicted

upon complainant by the careless manner by which the sewage of Chicago is deposited in the Illinois river, can only partially be appreciated or measured; and inasmuch as it is the well recognized duty of every state, representing the public, to look well after the health of its people in every regard, and to secure, if possible, the most desirable water supply, preventing unnecessary polluting and infectious material being deposited in it. And inasmuch as it has been truthfully said that typhoid fever is termed by scientists as a disease of civilization, "and for every death from it some one is criminally liable," and while it is also true that it is practically impossible to eradicate this disease, yet sufficient has been learned in recent years to know that it can be largely reduced and greatly avoided, the court should not and will not hesitate to decline to undertake to balance the inconveniences arising in a given case wherein the question of health, mental and physical suffering and the well-being of the people is involved.

The people residing upon the natural watershed of the Mississippi river have what may be termed a vested right, which guarantees to them the use of the water of the Mississippi river, free from the disease contaminating effects of any sewage discharges that may, by any possible means, be discharged into it from another watershed. Nature has prepared the Mississippi river as the means by which the waste and sewage discharges of the people residing upon its watershed may be carried away, and this, under the law, is subject to the supervision and control of the courts to the extent that no one shall have the right to make an unnecessary use of the river, or shall so disturb its natural condition as to render it unsuitable and unfit for the uses and purposes of those who may be required to use it at points below.

We take the broad ground that, in as much as it is necessary for large and populous cities to obtain their water supply from running streams, the discharge of sewage into the stream to such an extent as will render the water unsafe and unwholesome for domestic uses, can be enjoined or prevented by courts of equity. However, in the case at bar, we are not required to stand upon this proposition, for the reason that the Sanitary District of Chicago can not be given the right against the will and protest of complainant to use the Mississippi river as its drainage basin, nature having provided Lake Michigan for that purpose.

But upon the question of balance of conveniences as applicable to this case we call the court's attention to the fact that the citation from the American and English Encyclopedia of Law, 2nd Ed., Vol. 16, p. 363-64, is not applicable here for the reason that the editor adopted his language largely from the decisions of the courts in the following cases:

Bernard vs. Gibson, 7 Howard, 650.
North vs. Kershaw, 4 Blatch., 70.
Gold Mining Co. vs. Mining Co., 23 Cal., 82.
Scanlan vs. Howe, 24 N. J. Eq., 277.
Abraham vs. Myers, 29 Abbott's New cases, 384.
Morris vs. Prudden, 20 N. J. Eq., 530.

In the case of Bernard vs. Gibson, 7 Howard, 650, the facts involved were of minor importance, and related to a controversy existing between two individuals. Public interest was not concerned. The only point in that case which in any way bears upon the question at hand is made in the following language:

> "The hardships stated is an unanswerable objection to the operation of the injunction until all the

> matters shall be finally adjusted. If the injunction has been inadvertently granted the circuit court has power to suspend it, or set it aside until the report of the master shall be sanctioned. And unless the defendants below are in doubtful circumstances and cannot give bond to respond in damages for the use of the machines, should the right of the plaintiff be finally established, we suppose that the injunction will be suspended. Such is a correct course of practice, as indicated by the decisions of this court, and that is a rule of decision for the circuit court."

It might be here noted that the hardships, injustice and damage inflicted upon the complainant on account of the unwarranted conduct of defendants in the operation of the canal, or in the discharge of the sewage of Chicago into the Illinois river through the canal, is an unanswerable objection to its operation, and the hardships and injury existing are of such character as to warrant the granting of the injunction regardless of what may be the damage to respondent in dollars and cents.

In the case of Abraham vs. Myers, 29 Abbott's New Cases, 384, the point again involved was a mere private one, affecting private interests, and nothing in the language of the court can be construed, so far as this case is concerned, to warrant the statement made by counsel for defendants upon the question at hand.

The case of Scanlan vs. Howe, 24 N. J. Eq., l. c. 277, was one to compel the specific performance of an alleged agreement for the assignment to plaintiff of a contract for constructing a sewer, awarded by the corporate authorities of a municipality, and for an injunction against the defendant who claimed to be owner, by assignment, of the interest of plaintiff in said contract, and

to restrain him from executing the work. It will, therefore, be observed that this, too, was a suit involving only the rights of two individuals, the public in nowise being interested. The court, in concluding its opinion, said:

> "The complainant has a remedy at law. He alleges it is not adequate. If it is not, it must be because of want of pecuniary responsibility on the part of Howe. But this is not alleged. The defendant, Curtis, has answered all the equity of the bill. Under the circumstances of this case, especially taking into consideration the plaintiff's tardiness in invoking the aid of this court for the protection of his rights, and his omission to give notice to the innocent parties who are to suffer by the continuance of the injunction, it is more equitable to deny him the aid of an injunction than to subject them to the serious loss and damage which the continuance of the interdict will occasion. The court in such cases as this will weigh the comparative advantages and disadvantages of the injunction to the parties."

It will be well to notice the exact language of the court in the above case, as follows: "*The court in such cases as this* will weigh the comparative advantages and disadvantages of the injunction to the parties." This language of the court gives us to distinctly understand *that only in cases of that character will the court undertake to balance the conveniences*, or weigh the comparative advantages or disadvantages of the parties to the proceedings, and the effect the injunction may have upon either.

In the case of Gold Mining Co. vs. Mining Co., 23 Cal., 82, the question involved was one affecting defendant's right to

remain in possession of a mining claim, working it as its own, and expending large sums of money in developing it when plaintiffs claimed to have the right to the property. The court there undertook to balance the conveniences of the parties by saying that when the title to property is in dispute the question whether the parties are solvent and able to respond in judgment forms an important element in passing upon an application for an injunction pending the litigation. Plaintiffs in the case having set up no circumstances of the character above mentioned to sustain their application, the court refused to say the balance of convenience was in favor of plaintiff.

North vs. Kershaw, 4 Blatch., 70, grew out of certain property rights to a patent, and involved a controversy between two individuals. It may also be said to have no connection or bearing on the case at hand.

The injury inflicted upon complainant is apparent from the evidence introduced. This injury is brought about not by any act of what may be termed an upper riparian owner or resident, but by defendant, Sanitary District of Chicago, located upon Lake Michigan water-shed, and having no common interest with the inhabitants residing upon the Mississippi river water-shed. It is said in American & English Encyclopedia of Law, 2nd Ed., Vol. 30, page 377:

> "A person who is injured by the wrongful detention or obstruction of the waters of a water-course may maintain an action at law for the damages suffered, and courts of equity will, as a general rule, grant relief by injunction against the continued detention or obstruction. So the obstruction of a water-course in such manner as to flood the lands of an upper riparian owner may constitute a nuisance which he may abate in so far as will remedy the injury.

> "An upper riparian owner has no right, by emptying into a stream an artificial supply of water, or the water of another watercourse so as to increase the amount of water in the stream as to injure a lower riparian owner; and where the water is ponded by a dam the owner has no right by discharging the contents of the pond to increase the flow of the watercourse beyond its natural capacity, to the injury of the lower proprietors."

The above doctrine applies to the rights and privileges of riparian owners. And persons residing upon another watershed and attempting to discharge water therefrom into another by means of an artificial supply, or artificial stream or canal, are not given the right, under the law, to even a reasonable use of the water. He may be considered in law a trespasser, having no rights whatever in the premises. Therefore, an injunction should be granted against him in favor of a complaining party.

In this connection it has been said: "Every riparian owner is entitled to have the water-course flow by his land in an unpolluted condition, and one riparian owner has no right to unreasonably corrupt or pollute its waters to such an extent as to essentially impair its purity. Thus it is unlawful to cause the pollution of a water-course by the discharge therein of noxious or poisonous refuse from mills and factories, distilleries, tanneries, gas works, cheese factories, saw mills, mines or slaughter houses; by the discharge of sewage, either by a private individual or by a municipal or quasi municipal corporation, by the maintenance of extensive cattle and hog pens upon or near the banks of the stream or by the underdrainage therein of the water from a cemetery. If an upper riparian owner deposits in the stream matter which by the natural action of the water is car-

ried upon the land of lower riparian owners, he is liable for the injuries caused thereby."

The above rule is applicable to riparian owners, and much stronger must be its application when applied to those persons who do not reside upon the water-shed of the stream in question.

Attorney-General vs. Hackney, 20 L. R. (Equity), 626.

In the case of Indianapolis Waterworks Co. vs. American Strawboard Co., 53 Fed. Rep., 970, it was held that the discharge of refuse matter from the strawboard factory into a non-navigable river, used by a water company owning land fronting on and extending along said river, as a source of supply for furnishing a city, its inhabitants and others with water for domestic, manufacturing and other purposes requiring purity of supply, thereby fouling and polluting such stream, is necessarily a continuing nuisance, for which no plain, adequate and complete remedy exists at law, and injunction will lie to restrain such discharge. In the course of its opinion the court said:

> "It has been well said that the rights of a riparian proprietor, in so far as they relate to any natural stream, exist *jure naturae*, because his land has by nature the advantage of being washed by the stream; and as the facts of nature constitute the foundation of the right, the law should recognize and follow the course of nature in every part of the same stream."

Again in the same opinion it is said:

> "A riparian proprietor upon a non-navigable stream is entitled, in the absence of grant, license or prescription limiting his rights, to have the stream which washes his lands flow as it is wont by nature to flow, without material diminution or alteration. Every

riparian proprietor has the right to insist that the stream shall flow to his land in the usual quantity and quality and at its natural place and height. He owes the duty of permitting it to flow off his land to the lower riparian proprietor in its accustomed quantity, quality, place and level. The proprietor has no property in the flowing water which is not the subject of riparian ownership, but he may use it for any purpose to which it can be beneficially applied, without material injury to the rights of others. Any diversion or obstruction of the water which substantially diminishes its volume, or the depositing of any substance in the stream which corrupt or pollute the water to such a degree as essentially to impair its purity and prevent its use for any reasonable and proper purpose to which running water is usually applied, is an infringement of the rights of the owner of the land through which the stream flows. An action for damages may be maintained by a riparian proprietor for the pollution of the stream. So a perpetual injunction will be granted to restrain such pollution, especially if it is of a continuous nature, even when the plaintiff could only recover nominal damages at law, because of the inconvenience of repeated actions, and the danger of the acquisition of an adverse right to pollute it by its continuance for twenty years."

Again in the same opinion we find the following language:

"Where the right of a riparian proprietor to the use and enjoyment of the flow of a stream of pure and wholesome water, free from corruption and pollution,

> has been actually invaded and such invasion is necessarily continuing, and to operate prospectively and indefinitely, and the extent of the injurious consequences is contingent and of doubtful pecuniary estimation, the writ of injunction is not only permissible, but it affords the only adequate and complete remedy."

In Lewis vs. Stein, 50 Am. Dec., l. c. 179, the court said:

> "Being the owner of the land over which the stream of water flows, he has the right to use the water, but as this right is common to all the riparian owners, no one of them, by virtue of his title to the land, and his right to use the water incident thereto, can claim to use the water so as to corrupt or impair its quality, to the prejudice or injury of the others: Ang. on Water-courses, 20; Howell vs. McCoy, 3 Rawle, 256. The defendant, therefore, can not claim the right to injure the water by virtue of any title to the land, from whatever source derived. It is true, he acquired the right to erect a mill on the creek, and to use the water for this purpose, but the rights of those below him forbade him to so construct it as to render the water impure, or to corrupt or injure its quality."

It will be noticed that the court lays particular stress upon the fact that the riparian owner's right both to use the water and to construct the mill grew out of the fact that he owned the land over which the stream flowed. This doctrine can not apply to one who is not in a legal sense a riparian owner; or to one who does not reside upon the water-shed of the stream polluted, or is not a municipality situated upon the water-shed of such stream. In discussing the facts in the foregoing case, the court remarked:

"The only remaining question is whether the evidence shows that the sawdust injures the water. The witnesses state that the filmy substance found in the water was created entirely or in part by the sawdust. To what extent this substance impairs the sanitary qualities of the water the witnesses do not know; one, who was a physician, thought it did not render the water less healthful. We, however, think that the existence of such a substance in the water is an injury to it. To say the least, it renders the water less pure, and is *calculated to annoy and disgust* those who have it to use for the ordinary purposes of life, consequently must be an injury to it."

"Counsel for plaintiff in error, however, has urged that to enforce the penalty against defendant will compel him to abandon the use of his mill, or to alter its structure at considerable expense, and thus private property will be taken or destroyed for the public good without compensation. The whole error of this argument consists in not reflecting upon the strict rights of the defendant. He had the right, *by virtue of his title to the land*, to use the water, but not to abuse it to the injury of others. By his act he not only uses it, but, as the evidence shows, injures its quality. This he had no right to do; he obtained no such right, by virtue of his grant to the land, nor has he derived any such grant or authority from any source having power to grant it. He therefore has incurred the penalty by infringing upon the rights of others, and for injuring the water, and for this he must be responsible."

It will be noticed that the judgment of the court in the foregoing case is based upon the rights of defendant by *virtue of his*

title to the land over which the water flows. If, then, a person who owns the land over which a navigable or non-navigable stream may flow is not entitled to an unreasonable use of the water certainly one who has no interest whatever in the land, neither as a riparian owner nor otherwise, has no right to make an improper use of the water, or to so change its natural condition as to render the water less pure, or of such character as will be calculated to annoy and disgust those who have to use it for the ordinary purposes of life.

In Dwight vs. Hayes, 150 Ill., 273, is direct authority upon the proposition that a city may be enjoined from discharging its sewage into a running stream by a riparian owner below the point of discharge. The court in this case refers to Gould on Waters, Sec. 546, where we find the following language:

> "Authority over sewage is no authority to permit a nuisance. The owner of land upon a stream below the city is entitled to an injunction against injury by the outflow of sewage. So an injunction will lie to prevent the opening of additional sewers into a stream in such a manner as to render the water unfit for use, and it is not a defense that the city cannot lawfully enter upon the premises of those who use the sewer for the purpose of abating a nuisance. And if a few householders upon a stream have used it as a drain a modern board cannot found a prescriptive right to corrupt the stream upon such usage. If any nuisance of this kind is shown, though causing inconsiderable damage, equity will enjoin its continuance, and in deciding upon the rights of a proprietor to an injunction against such nuisance the court will not consider the convenience of the public. The fact that a large population will be affected by the interruption of the use of

> the system of sewers is immaterial where the rights of an individual are invaded. The inconvenience is one of the public's own creation, and should be borne by it rather than the individual."

And so in the case at bar. The inconvenience is one of defendants' own creation and should be borne by it rather than by complainant.

High on Injunctions lays down this doctrine: Frequent ground of application for a preventive aid of equity is found in cases by the pollution of water from the flow of matter into such streams whose waters are thereby injured and rendered unfit for use. In cases of this nature the preventive jurisdiction of equity is well established, the general doctrine being that the fouling or polluting of water by such usage constitutes a nuisance and affords sufficient ground for relief by injunction. In conformity with this doctrine, the owners of land upon a stream below a city may enjoin such city authorities from polluting the river by such usage.

If this doctrine can be enforced against a municipality located upon a water-shed of a stream involved, much greater is the reason and necessity of enforcing it as against the objectionable conduct of a municipality located upon an adjacent water-shed wherein an attempt is made to divert the sewage and filth from the basin prepared by nature for it into the adjoining drainage basin, thereby compelling the inhabitants residing upon neighboring water-shed to be subjected to the inconvenience and annoyance of the waste, filth and objectionable refuse of their unnatural neighbors.

In this connecion, we refer to Spence vs. McDonough, 77 Ia., 460, and Ferguson vs. Manufacturing Co., 77 Ia., 576. In the last above case the court held that:

"Where the upper owner by the unreasonable use of a stream pollutes it so that the water as it flows upon the farm below is not only useless for stock and domestic purposes, but also is a source of sickness, pain and discomfort to the lower owner and his family, he is entitled to recover not only the difference in the rental value of the farm on account of the nuisance, but also such special damage as he may have suffered, including that resulting from sickness, pain and discomfort."

In Harris vs. McIntosh, 133 Mass., the court held that the owner of land on a natural stream may maintain a bill in equity to restrain another land owner on such stream from carrying on business in such a way as to pollute the water of the stream, to the injury of plaintiff.

In Attorney-General vs. City of Patterson, 58 N. J. Eq., 1, the following propositions were determined:

1st. Owners of land on the banks of a stream are entitled to have the water flow to them unpolluted.

2nd. Pollution of a river, by the discharge of city sewage gathered from a large area and caused to flow into the stream by artificially-constructed grades, cannot be justified as a natural and reasonable use of the river.

3rd. The public act authorizing a city to discharge its sewage according to maps exhibiting sewer outlets, etc., does not license a city in discharging such quantities of sewage as will pollute the river.

4th. Riparian owners who sue to restrain a city from discharging sewage into a river as soon as the sewage begins to contaminate the waters are not guilty of laches.

The above principles were determined by the court in a suit brought by the attorney-general on behalf of about twenty land owners residing upon the river alleged to be polluted by the city. 500,000 people were dependent upon the Passaic river as a sewage outlet, yet the court held that the twenty land owners had rights which could not be invaded or violated on account of the public convenience to the 500,000. It will be noticed that this was a suit instituted by riparian owners against a municipality situation upon the water-shed of the river in question, in fact, upon the banks of the river, and the city itself occupied the position of an upper riparian owner. In the case at bar, the city of Chicago does not occupy the position of a riparian owner, but is a foreigner to such rights.

In Strobel vs. Kerr Salt Co., 164 N. Y. Rep., p. 304, the court held:

> "While the courts will not overlook the needs of important interests, nor hamper them for trifling causes, they will not permit substantial injury to neighboring property, with a small but long established business, for the purpose of enabling a new and great industry to flourish. They will not change the law relating to the ownership and use of property in order to accommodate a great business enterprise. According to the old and familiar rule, every man must so use his own property as not to injure that of his neighbor, and the fact that he has invested much money and employs many men in carrying on a lawful and

useful business upon his land does not change the rule nor permit him to permanently prevent a material portion of the water of a natural stream from flowing over the land of a lower riparian owner, or to so pollute the rest of the stream as to render it unfit for ordinary use."

"When one riparian proprietor, by his use, causes deterioration of the water of a natural stream, the fact that others are using it in the same manner instead of preventing relief may require it, and even if the damages are slight, where the act complained of is such that by its repetition or continuance it may become the foundation or evidence of an adverse right, a court of equity will interpose by injunction."

A person owning land has no right to rid it of surface water by collecting it in artificial channels and discharging it through or upon the land of an adjoining proprietor. This rule is alike under the common and civil law.

Gould on Waters, Sec. 271.

If, then, as has been uniformly held, a person can not rid his land of surface water by collecting it into artificial channels and then discharging it upon the land of his neighbors, although both parties may reside upon the same water-shed, how much more reason is there in applying the rule against the right of a person residing upon an adjoining water-shed to cut through a natural barrier so as to discharge his waste and filth upon persons residing upon the neighboring water-shed. It has been said:

"A land owner may drain his land by artificial ditches and thereby cause the water to pass more rapidly and with increased volume on the adjacent

land of the lower proprietor *if the same water would not naturally flow in a different direction,* and he acts with a proper regard for his neighbor's welfare."

So applying this rule, defendants were without authority to construct the canal in question for the purpose of discharging the sewage of the great city of Chicago into the Illinois and Mississippi rivers, and thereby burdening the people of the Mississippi valley with the elements of danger to life, health and society, contrary to the plan which nature has devised.

In the case of Anderson vs. Henderson, 124 Ill., 164, the ground of relief, as stated by the court, in its opinion, is as follows:

> "At the point where the ditch was so filled up there is an elevation of land that is naturally the dividing line between the waters that should flow east, towards complainant's land, and the water naturally flowing westward from him, and that at the time the ditch was filled up, defendant agreed, and it was decided by mutual friends of the parties, to whom the matter was referred for determination, that such ridge or elevation of land was the natural dividing land between the waters that should flow towards complainant and those that did not flow towards him, and that then and there defendant pledged himself that such ridge should always be the dividing line, and that the surface of the same should not at any time be changed so as to divert water across or through such ridge onto complainant's land, and in consideration of which complainant agreed to receive nominal damages, and to pay the costs in the common law suit. The grievance now complained of, and against which relief is

sought in the present suit is, that defendant has many times since the other transaction occurred threatened to re-open such ditch and wrongfully to divert large quantities of water from the ponds and sloughs on defendant's land out of its natural course."

In commenting upon the rights of the parties in question the court said:

"It is obvious from this statement of the pleadings and findings of the court, the questions involved are purely questions of fact, and as to which it must be conceded in the outset the evidence is quite conflicting. The law which counsel for defendants insists is applicable and should control is so well understood it need not be discussed. It is that the owner of a higher tract of land has the right to have the surface water falling or coming naturally upon his premises, by rains or melting snow, pass off the same through the natural drains upon or over the lower or servient lands next adjoining, and the owner of the dominant heritage has, and ought to have, the right, by ditches and drains, to drain his own land into the natural and usual channels which nature has provided, even if the quantity of water in that way thrown upon the next adjoining lower lands be thereby increased. The rule in this respect is a just one, and is indispensible to secure proper drainage, in many instances necessary to render land tillable. While the owners of low lands shall receive all water that naturally flows from the next higher lands, the owner of the higher lands may not open or remove natural barriers, and let onto such lower lands water that would not otherwise naturally flow in that

direction. That would be to subject the servient heritage to an unreasonable burden, which the law will not permit, and against which the owner ought reasonably to have protection. The principles of law that govern in such cases are in harmony with good neighborship, and ought to be readily acquiesced in."

The foregoing case is quoted approvingly in the case of Dayton vs. Drainage Commissioners, 128 Ill., 271.

In Jackman vs. Arlington, 137 Mass., the court said:

"We take the law to be that the owner of land has no right to collect the surface water into an artificial stream and discharge it upon adjoining lands in such quantities and in such manner as materially to injure the land; but that such owner has the right to collect the surface water in the natural drainage of his land into an artificial stream and discharge it into the natural course on his own land, if the water-course is the natural outlet of the waters thus collected, even though by this artificial arrangement the flow of the waters is accelerated and the volume at times increased, provided this is done in the reasonable use of his own land, and that the discharge is not beyond the natural capacity of the water-course, and the land of the riparian owner is not thereby overflowed and materially injured; *but he has no right to subject the land of another to a servitude of running water to which it is not naturally subject.*"

In this last case the court cited the following authorities:

White vs. Chapin, 12 Allen, 516.
Curtis vs. R. R., 98 Mass., 428.

Carter vs. Thruston, 58 N. H., 204
Noonan vs. Albany, 72 N. Y., 470.
McCormick vs. Horan, 81 N. Y., 86.
Barkley vs. Wilcox, 86 N. Y. 140.
Hughes vs. Anderson, 68 Ala., 280.

The law of necessity may, to some extent, justify the right of a riparian owner to discharge objectionable material into a running stream, but the fact that he resides upon the stream and is recognized as being the owner of a "dominant heritage" does not afford him the privilege of making objectionable discharges into the stream at will. Even under these circumstances the use to which he subjects the stream must be reasonable, and in a sense necessary. It is this principle of law, growing out of necessity, that must be recognized by everyone. It can not be said, however, that this will, under any circumstances, authorize the conduct such as is complained of in the bill in this case, or will in any wise recognize the right of the Sanitary District of Chicago to discharge its sewage into the artificial canal, and thence into the Illinois and Mississippi rivers against the wish and protest, and to the damage and detriment of complainant.

The fact that the sewage of the city of Chicago, containing a population of more than two millions people, is discharged directly into the canal, coupled with the fact that typhoid fever is highly prevalent in that city, is sufficient in and of itself to create an uneasiness, great suspicion and discomforture on the part of the people residing on the Mississippi river below the mouth of the Illinois river, who are necessarily compelled to use the water of the river for domestic purposes. Defendants are forced to admit the discharge of pathogenic bacteria from Chicago into the canal, and thence into the Illinois river. In their defense they rely solely upon the assumed fact that all of the

pathogenic bacteria disappear or perish before the mouth of the Illinois river is reached. It is admitted that these germs live for a time in constantly decreasing numbers. The period of life fixed by defendants' experts is limited to from four to six days. This is an arbitrary period, in conflict, in every particular, with the experience of sanitarians throughout the world. No reasonable premise or competent evidence was interposed by defendants upon which a limitation of this sort can be based or the longevity of the pathogenic germs fixed at so short a period.

It is admitted, not only by defendants' expert witnesses, but by defendants' counsel, in their briefs, that the longevity of these germs depends largely upon their respective environments as to water, polluting material, temperature of the water and the atmosphere, velocity of the stream, and lastly, but not least, the special resistant forces, and vitality of each particular organism. Like the human family, they have different ages. The life of each germ can not be measured by scientifically prepared formulae, or by any means, or from any information or knowledge within the scope of human ingenuity. These germs, so far as life and death are concerned, occupy relatively a like position with the human race or the animal kingdom. The life of a germ like an individual may be approximated, but nothing definite can be determined upon until its life-course is run. Man may live to be a hundred years old, dependent largely upon his environments and his great powers of vitality. On the other hand, he may die early, superinduced by some unknown cause, special environment, or by some constitutional ailment. So the germs of disease usually transported by water may live outside the human system for a short or considerable length of time.

Aside from the opinions of specialists who have testified for defendants in this case, it is generally believed , as shown by the evidence, that typhoid bacteria will live in a running stream for

a period of from five to thirty days. The evidence of Mr. Rudolph Herring, the sanitary engineer who took the stand in behalf of defendants, shows that he, during his many years of experience, has invariably followed the formulae prepared by Dr. Hiram F. Mills, chairman of the state board of health of the state of Massachusetts, in which the longevity of the germ is fixed at a maximum of twenty-five days, with constant reductions from the first to the twenty-fifth day. This table was introduced by Mr. Herring, and great stress was laid upon it by him for the purpose of showing the approximate extent of typhoid infectious material reaching St. Louis from Chicago, measured by a comparison of the velocity of the stream with the number of inhabitants residing upon the Illinois water-shed and within the Sanitary District of Chicago.

The court will observe, from reading the testimony of defendants' experts, that while they express an opinion to the effect that typhoid organisms will perish in the Illinois river before Grafton is reached, yet they were each compelled to admit that the opinions so expressed by them were at variance with the general belief and judgment of sanitary scientists throughout the world. The opinion of these witnesses not only conflicts with the general belief of persons in position to know, but also are in direct conflict with the bacteriological and chemical evidence interposed by both parties, as well as conflicting with the fact that there has been a large increase in deaths from typhoid fever in St. Louis since the opening of the drainage canal; that no other reasonable explanation for its occurrence than the opening of the canal and the discharge of the sewage of Chicago into it can be found, nor can these opinions, which stand as the fancy of each individual witness, be considered by the court as preponderating over the testimony of complainant, and the

opinions of the experts, chemists, bacteriologists, sanitary engineers and epidemiologists who testified in its behalf.

All of the testimony considered, it can not be denied but that infectious material is discharged into the Illinois and Mississippi rivers by means of the drainage canal, and that there is not only an actual impending danger to the lives, health and comfort of the people of the State of Missouri, but that there has been an actual injury inflicted upon them.

Aside from the foregoing, it can not be denied that by defendants' invading the province of nature and undertaking to divert, disarrange and destroy nature's true purpose in providing two respective separate and distinct water-sheds for the people living upon the drainage area of the Mississippi river and those residing upon the drainage area of Lake Michigan, such an invasion of a right has been made as entitles complainant to relief.

"The fact that the running of the water did no appreciable or actual injury to the owner of the lower lot is immaterial. The law implies nominal damages from the invasion of a right."

White vs. Chapin, 12 Allen, l. c. 520.

So by the invasion of the right in question the law implies nominal damages to plaintiff, and this regardless of the fact that actual damages have been shown.

If the controversy involved was one affecting the private rights of two or more individuals, and the public had no concern therein, the court might, under some circumstances, undertake to balance the convenience, and upon the result of such a determination grant or deny the injunction as set forth in the cases referred to by defendants in their brief under this head.

Where a necessary water supply is being put to an unnecessary use, the court will not attempt to balance conveniences be-

tween the parties, but will preserve the water in its natural condition, as near as may be, for the benefit of those who are compelled to use it.

In nearly all of the cases where the court has attempted to measure or to balance conveniences, it has concluded by leaving the party to his redress at the hands of a court at law, holding the party complainants to have adequate remedy.

All things considered, if the Sanitary District of Chicago was situated upon the water-shed of the Mississippi river the doctrine of measuring conveniences might, to some extent, be invoked, for the reason that the Mississippi river would be the natural outlet for its sewage, and it might then be said to have the right to use such means of discharge so long as it did not injure the well-being and safety of those residing upon the lower stream.

The case of Richards, Appeal 57 Pa. St., 114, cited at length by defendants, was one involving the right of an iron manufacturer to operate his factory in close proximity to the dwelling house and cotton factory of the plaintiff, the plaintiff's dwelling house being situated on a bluff above the nearest furnace of defendant, which brought its first floor about on a level with the top of the puddling stack. When the wind was towards plaintiff's house and from the furnace the consequence was that it was at times enveloped in coal smoke thrown out of the chimneys of the furnace. This condition operated undoubtedly to injure the dwelling house as a dwelling, and injury was also caused to the cotton factory, as the smoke blackened the stock and rendered the fabrics less salable. *The court found from the facts that it was necessary for the defendant to use bituminous coal, and that for the work of puddling no smoke-consuming device could be applied.*

Under the circumstances enumerated in the above case it was not unnatural for the court to have held that by balancing conveniences between the parties complainant was not entitled to the injunction prayed for, as defendant had a natural right to manufacture iron and to operate his furnaces. The court, however, recognized its right, in the event it be practicable, to regulate defendant's business, if possible, and to grant such an injunction as would give plaintiff all the protection possible, and at the same time work the least possible inconvenience to defendant. Having found, however, that it was necessary for defendant to use bituminous coal, and that for the particular work in question no smoke-consuming device could be applied, it doubtless acted rightly in denying the injunction and thereby refusing to practically confiscate defendant's property.

In the case at bar, defendants are not possessed of either an implied, natural or acquired right to discharge its sewage into the drainage canal. So far as the parties here are concerned, the defendants occupy the position of absolute strangers, trespassers having no rights in common to use the waters of the Mississippi for any purpose whatever, applicable to the law relating to riparian ownership, it having been held that the law with reference to riparian ownership and the use of streams by persons residing upon its banks, or upon its water-shed, applies alike to persons, individuals and public municipal corporations.

Gould on Waters, 272.
Plummer vs. Sturtevant, 32 Me., 325.
New Albany vs. Lives, 21 Ind. App., 380.
O'Brien vs. St. Paul, 25 Minn., 331.
Aurora vs. Love, 23 Ill., 521.

Equity will not refuse to protect one in the possession and enjoyment of his property merely because his right is less valuable to him than the power to destroy it may be to another or the public.

Sullivan vs. Steel Co., 208 Pa., 540.

IV.

THE FACT THAT CERTAIN MUNICIPALITIES IN THE STATE OF MISSOURI DISCHARGE SEWAGE INTO THE MISSOURI AND MISSISSIPPI RIVERS DOES NOT JUSTIFY THE CITY OF CHICAGO IN DISCHARGING ITS SEWAGE INTO THE CANAL, THEREBY FORCING IT UPON THE PEOPLE OF THE MISSISSIPPI VALLEY, AND BURDENING THEM WITH AN INCONVENIENCE NOT INTENDED BY NATURE.

It is insisted by defendants in their brief and argument that if complainant contributes to the condition which it claims in its bill would injure it as a State, it cannot obtain equitable relief on the ground of the fundamental principle that "he who seeks equity must do equity," and "that he who comes into equity must come with clean hands."

A number of authorities are submitted by defendants upon this proposition, all of which go to the effect that where two parties are guilty of committing the same nuisance one of such parties so in default can not institute proceedings against the other—this on the well known grounds set forth in defendants' brief. This proposition was completely covered by us in our original brief, under the head of "Contribution and Exoneration."

The authorities cited by defendants have reference to cases where both parties to the action were jointly interested in the preservation of the water supply in its natural condition, and were riparian owners upon the same stream. Such conditions do not pertain to the case at bar.

Applying the doctrine that the court will measure conveniences between parties litigant, so forcibly presented by counsel

for defendants in their brief, we submit that, upon this particular proposition, the court will take notice of the fact that the Mississippi river constitutes the only practical means of carrying away the waste and sewage from the inhabitants residing upon its watershed, and, under the controlling decisions, they may have the right to make reasonable use of the river for this purpose, so long as no injury or injustice is done lower riparian owners. This rule has been adopted, as heretofore stated, on grounds of public necessity. It does not apply to defendants in this particular litigation, for the reason that Lake Michigan constitutes the natural drainage basin of its watershed. Our position in this matter is that while large and populous cities may use a stream for the purpose of discharging sewage and waste, yet such discharges can not be made as will materially affect the value of the water as a supply for domestic purposes; and if it be put to an unreasonable use in this respect, an injunction will lie against such city by a lower riparian owner who is naturally forced or compelled to use the water of the stream for living purposes.

The fact that the city of St. Louis may have a cause of action against some other city in Missouri, or elsewhere, situated upon the banks of the Missouri or Mississippi rivers, and does not see fit to enforce its rights in the premises, constitutes no reason why the defendant city of Chicago should be permitted to continue the nuisance complained of. The fact that complainant does not proceed against other cities occupying the position of owners of a superior heritage and discharging sewage and waste into the Mississippi river, alike constitutes no reason why defendant should continue the commission of the nuisance herein complained of.

Every riparian owner is entitled to have a water course flow by his land in an unpolluted condition, and one riparian

owner has no right unreasonably to corrupt or pollute its waters so as to essentially impair its purity.

Am. & Eng. Enc. of Law, 2nd Ed., Vol. 30, p. 408.

This doctrine, which may be construed into the right of a riparian owner to use the water only to such an extent as will not corrupt or pollute it so as to essentially impair its purity, does not apply, and has never been made to apply, to persons other than riparian owners. In other words, one person who in no way occupies the position of a riparian owner can not invoke this doctrine in support of his right to pollute a running stream prepared by nature as the only practical means for a water supply of a large and populous community; and inasmuch as he does not occupy the position of a riparian owner, and is not the owner of a "superior heritage," every reason which under any circumstances justifies the pollution of a stream fails of its application. Such person is to be regarded as a trespasser and wrong-doer.

Situated as defendants are, having no right whatever to pollute the water on the general ground of riparian ownership, and being regarded by law as wrong-doers and trespassers, they are not in a position to justify their conduct because some municipality belonging to complainant may, to a slight extent, necessarily contribute to the pollution of the stream in question; the pollution sought to be justified by defendants is altogether artificial and unnecessary.

V.

THE EVIDENCE OF WITNESS E. E. LOCKRIDGE, WHO TESTIFIED FOR COMPLAINANT AS TO THE CONTENTS OF THE RECORDS IN THE MORTUARY OFFICE OF THE CITY OF ST. LOUIS, FROM PERSONAL EXAMINATION, WAS ADMISSIBLE.

Defendants object to the consideration by the courts of the testimony of witness E. E. Lockridge, who testified on behalf of complainant. The objections made and authorities cited are not applicable to the testimony of this witness, or its admissibility.

Every death, from any cause whatever, is required by ordinance to be reported by the attending physician or the coroner to the Health Department of the city of St. Louis, giving the cause of death, together with such other information as may be of value to the Health Department. These reports are made in such form as show the age of the decedent, the cause of death, and the date of death and the locality. As these reports are made to the Department the clerk in the mortuary office is required to record them regularly in books kept for that purpose. These books contain no classification as to age, names or causes of death, each death being recorded in regular numerical order, regardless of compilations or tabulations. These records have been kept for a number of years, and since 1895 consist of eleven or twelve large volumes, each containing several hundred pages, each book, perhaps, two feet in height, properly ruled so as to set forth all of the information and remarks given by the reporting physician, coroner or undertaker.

Recognizing the absolute impracticability of introducing these books in evidence, as well as the inadvisability of under-

taking to secure a certified copy of them, Mr. Lockridge was put to work by complainant, in the offices of the Health Department of the city of St. Louis, after complainant had satisfied itself of his experience, learning and ability to make a proper examination. This work required about three months of diligent labor, going over the records carefully, selecting each death from typhoid fever, and also each death reported therein as being caused by malaria, typhoid-malaria, typho-pneumonia, intermittent, remittent and other kindred fevers.

Mr. Lockridge shows that as the books were examined by him and the information obtained, it was carefully verified in order that no mistakes should be made.

Had the books themselves been introduced in evidence before the commissioner they would have constituted in and of themselves no intelligent or comprehensive evidence. Had complainant secured a certified copy of them, such copy would have represented more solid, written material than is perhaps contained in all of the testimony taken in this case.

Knowing these books to be carefully guarded in vaults, and not allowed to be taken from the mortuary office, and knowing, if introduced without a careful examination beforehand, such as was made by Mr. Lockridge, they would be absolutely valueless and incapable of being comprehended by anyone, so far as the issues in this case are concerned; and realizing also that a certified copy of the books would be as useless to the courts as the originals, the services of Mr. Lockridge were obtained, and his testimony introduced for the sole purpose of giving absolutely correct data with reference to the number of deaths that had been reported by the physicians of St. Louis as occurring from typhoid fever and other kindred diseases.

During the examination of Dr. Ravold, on behalf of complainant, certain of the published reports of the Board of Health,

so far as death from typhoid fever was concerned, were read in evidence. This had been verified, and no objection was made to the correctness of the statements contained in them regarding typhoid deaths.

Afterwards, presumably for the same purpose, defendants sought to introduce all of the published health reports of the city of St. Louis, from 1890 to the date of the taking of the testimony. In the examination of their witnesses defendants sought to criticise and discredit the correctness of these reports and to emphasize the fact that from the general experience of scientists a large number of deaths reported as typho-malaria, malaria, intermittent, remittent, etc., was in reality caused by typhoid. In view of the fact that the published health reports did not set forth under the proper columns all of the diseases in which deaths were included and tabulated, complainant thought proper to make the investigation in question, in order that all inaccuracies and misstatements of facts which might have been made, in an innocent manner by the persons compiling the health reports, would not be considered by counsel and the court in such manner as to produce an unauthorized and unwarranted conclusion with reference to the actual number of deaths occurring on account of the respective diseases.

When Mr. Lockridge was put upon the stand defendants did not at first object, nor was an objection made to certain conclusions drawn from tabulations made by him from the original records in the mortuary office.

However, in justification of complainant's right to introduce the evidence in question, we call the court's attention to the following statements made by counsel during the taking of the testimony, and in moving to strike out certain questions and answers in the cross-examination of Dr. Edward W. Saunders. Record p. 7601:

"MR. TODD: I move to strike out the answer and question for the reason that the column known as typho-malaria, intermittent, remittent, congestive, simple and continued fever not only contains death from such diseases, but other diseases, as evidenced by the fact that in the health report the persons who compiled it have placed other deaths in that column, and all statements based thereon would be incorrect, and can not be relied upon because the column itself calls attention to the fact that deaths from other diseases are placed therein.

"MR. TODD: In reply will state that the witnesses on the side of the complainant in this case, especially the epidemiologists, predicated their argument that the drainage canal was responsible for the typhoid conditions in the city of St. Louis, upon the Board of Health reports of the city of St. Louis, and that the injury which St. Louis sustained by virtue of the opening of the drainage canal was manifest in the Board of Health reports in the city of St. Louis, and there has been no other evidence offered in this case to sustain the claim except that of the Board of Health of the city of St. Louis.

"MR. JEFFRIES: In answer to counsel I will state that we accept the truthfulness of what is shown in the Board of Health reports of deaths from typhoid fever, and that such deaths contained in the published health reports is the only statistics that were offered by the plaintiff. I suggest also that counsel himself has used the column with reference to remittent, intermittent, congestive and other diseases, and that it was introduced by him and not by complainant, and that

the column, so introduced by him, especially calls attention to the fact that deaths from other diseases are included therein.

"MR. TODD: *In reply counsel for defendants admit the truth of every word counsel has just uttered,* but complains that complainant should have offered the remittent, intermittent, typho-malaria and congestive fever columns in order to arrive at a correct conclusion as to typhoid conditions in the city of St. Louis, and complains failure to do so cannot militate against defendant having done that what counsel charged us with having done.

"MR. JEFFRIES: I will state for the benefit of counsel that the complainant did not introduce in evidence the published report of the Board of Health, wherein the statement is made that a certain number of deaths occurred each year, under the head of remittent, intermittent, typho-malaria, congestive and simple continued fever, because it would have been unfair, and would have misrepresented the fact, that column stating and calling attention to the fact that other diseases were included therein."

During the testimony of Mr. Lockridge this question was asked:

"Will you state whether or not, in your opinion, a comparison of the typhoid fever deaths previous to 1896 with those subsequent to 1896 would yield, or would be practicable as a means of determining whether or not typhoid fever had or had not increased in St. Louis after the opening of the Chicago Drainage Canal, January 17, 1900?"

To this question Mr. Todd, counsel for defendants, interposed the following objection:

> "Object to the question for the reason that it is in rebuttal, as the entire typhoid conditions in St. Louis for ten years prior to the opening of the Drainage Canal were introduced by Dr. Ravold, and supplemented by charts of various kinds as to the typhoid conditions of St. Louis, and is, therefore, incompetent, irrelevant and immaterial."

In answer to the above question Mr. Lockridge made the following statement:

> "I do not believe that any such comparison is either practicable or feasible, for the reason that while previous to 1896 the intake of the waterworks of the city of St. Louis exposed the water supply to infection coming from the sewers of the city, and during 1894 and 1895 the intake was removed to a point further up the Mississippi river, at the Chain of Rocks, above any such contamination.
>
> "In order to show the great change in typhoid fever mortality of the city of St. Louis at the time the intake was moved, I have prepared a diagram which serves to illustrate this point, as well as ascertain other points to which I have occasion to refer hereafter."

Mr. Todd then moved to strike out this answer practically for the same reasons stated in his objection to the question. (pp. 7823 and 7824 of printed record.)

In qualifying the witness upon the question here involved, the following questions were asked and answers obtained:

"Q. From what source did you get the data upon which these charts are based, and which you have read in evidence?

"MR. TODD: Object to the question for the reasons heretofore stated.

"A. This data was obtained by me in the office of the clerk of the mortuary office, or mortuary department, in the city of St. Louis. I have already read it in evidence.

"Q. Where did you get the estimates of the population of the city employed by you in preparing these charts?

"A. I used the same estimates that were used and submitted in evidence by Dr. Barker and Prof. Jordan. (Dr. Barker and Prof. Jordan testified on behalf of defendants.)

"Q. Mr. Lockridge, state the character, in a general way, of the examination you made of the records in the mortuary office of the Health Department of the city of St. Louis, in securing this data, and the mortuary death records of the various diseases mentioned.

"A. I copied the date of death, the name, the age, the residence in the city, and if the death occurred in a hospital, the name of the hospital, and the residence address from which the case had been transferred to the hospital; the ward and the sanitary district given in this record, and contributing cause of death named by the physician of every case of typhoid, typho-malaria, remittent, intermittent, congestive, continued, enteric, bilious, typho-pneumonia, or any other deaths referred to by me. In doing this, I ex-

amined the cause of death of every person dying in the city of St. Louis during the eight years from 1896 to 1903, inclusive.

"Q. From what book or books in the office of the mortuary clerk did you obtain this data? Also state how the books from which this data were obtained are made.

"A. In order that a burial certificate may be issued, the attending physician or the coroner must bring to the mortuary office a certificate of death, showing the age and cause of death in each case. These certificates contain the age at death, also quite frequently the duration of the illness, the contributing cause, and any remarks of the physician, and the residence and place of death of the deceased. The data from these certificates is then copied into large books, which are so ruled that each part of the data referred to is recorded in a separate column, this record being made by an assistant. Every death is then checked by the mortuary clerk. These books are then regarded by them as the official records of this death, and any certified copies of death made to insurance companies or others are made from these books. These books are all kept, with great care, in a large vault.

"Q. These books about which you have spoken in your last record are the only mortality records in the mortuary office of the Board of Health of the city of St. Louis, are they not, from which the data which you obtained can be secured?

"A. I believe they are; I was so informed.

"Q. State whether or not the officer in charge of

these books permits them to be taken from the office.

"A. He will not.

"Q. State whether or not these records, as observed by you while you were working among them, were not in daily use?

"A. These records were in daily use.

"Q. State whether or not you made inquiry as to whether and how these books may be taken out of the mortuary office, if at all.

"A. I made such inquiry and was informed by the clerk in the mortuary office that such records might not be taken by anyone from the office, and that if it was necessary to use them at any time outside, permission must be secured from the Commissioner" (meaning the Commissioner of Public Health), "and subpoena issued and a regular member of the staff must always accompany them.

"MR. JEFFRIES. I will state for the benefit of the court that I would be very glad indeed to introduce these books in evidence, but on account of their public importance I am unable to do so, on account of its being absolutely necessary that they remain in the archives of the mortuary office.

"*I will also state to counsel for the defendants that if he desires I will have this book produced before him, subject to his inspection, if it is possible to do so.*

"MR. TODD. *In reply I will state that counsel for defendants desires nothing, as complainant has the burden of making out their own case, according to legal evidence.*

"Q. How many of these books are there, as well as you remember?

"A. I should think eleven or twelve.

"Q. How large are they—about how many pages?

"A. Several hundred pages. They are perhaps four inches thick and the height of the page is over two feet.

"Q. Have you your original transcript from the record, showing the data you have introduced in evidence, together with the names of the decedent?

"A. I have.

"Q. Will you present those?

"A. I will.

"MR. JEFFRIES: I desire to offer these as complainant's rebuttal exhibit for identification.

"Which said exhibits are produced and marked by Commissioner 'Complainant's Rebuttal Exhibit 1 for Identification.'" (Record, pp. 7938-7942, inc.)

From the foregoing it will be observed that no attempt was made to withhold material and competent evidence from defendants in the cause. Everything possible was done to satisfy the objection of defendants' counsel upon the absence of the books in question. An offer was made to produce them if it could be done, and to submit them to opposing counsel for inspection. And while it is plain from the statement of Mr. Lockridge that it was practically a physical impossibility, aside from the other reasons stated, to introduce the books in evidence, yet counsel for defendants said he had no desire to inspect the books, did not deny that they were in existence, that they had been accurately copied, or that the facts which Mr. Lockridge had obtained from them were not correct and accurately made, but relied solely upon the following statements:

"In reply will state that counsel for defendants desires nothing, as complainant has the burden of

making out their own case, according to legal evidence."

We submit that from the facts produced before the Commissioner, with reference to our inability to secure these books in evidence, no complaint should now be urged because of the failure; in fact, everything was done that was possible, and this is ample justification for the introduction of what may be termed secondary evidence.

The authorities submitted by defendants in opposition to the introduction of this particular testimony are not questioned by us. By a careful study of each particular case it will be found that the facts were entirely different, and the application there given the rule does not here apply. In practically every instance, so far as defendants' authorities are concerned, the question involved is proof of the contents of a written instrument without first showing inability to produce it in evidence, and without any excuse whatever for not producing it.

Some of the authorities cited by defendants in this connection, in fact, sustain our position. In Mar s vs. Winter, 19 La., 445, the court said:

> "The best evidence should be produced that is within the power of the parties to procure."

So we say in this case that the best evidence within our power was produced, so far as the contents of the mortuary records of the city of St. Louis were concerned.

In Richards vs. Stewart, 2 Day, also cited by defendants, we find the doctrine expressed in the following words:

> "Let this fundamental maxim of law be thoroughly examined, and it will not be found to support the objection. What is its extent? It is always limited to

the particular circumstances of the case. When from the particular circumstances of the case no better evidence can be brought, though better may be imagined, and may actually exist, the rule does not require its exclusion.

"The reason of the rule that the withholding of the best evidence furnishes a presumption that if produced it would operate against the party, may serve to show how far the rule is to be carried. Where it is not in the power of the party to produce the best evidence this reason does not exist."

So in Rinaldi vs. Rives, 1 Stewarts, 174, it was held that:

"Where there is written evidence in the power of the party to procure, parol evidence is inadmissible."

We call the court's attention to the fact that here, as in all other cases, if it be found that the party cannot produce the best evidence, secondary evidence will be admitted.

In Renner vs. Bank of Columbia, 22 U. S., 581, it was held that:

"Secondary evidence of the contents of written evidence is admissible if there is no suspicion raised that the original paper is kept back by design, and it is of that description that no doubt can arise as to the proof of its contents."

So also in U. S. vs. Reburn, 31 U. S., 350, the court said:

"If the non-production of a written instrument is satisfactorily accounted for, evidence of its existence and contents is admissible."

In Clark vs. Hornbeck, 17 N. J. Eq., the court held:

> "A reasonable assurance that evidence of a higher nature is not withheld or suppressed is all that is required as a ground for the admission of secondary evidence."

In this case we have shown to the court that the record in question was of such volume, and the information or evidence desired of such character, that it could not be readily ascertained or observed by the court upon an examination of the books themselves, but that a compilation from them must first be made, in order to be of value.

> "Where a fact could be ascertained only by the inspection of a large number of documents, made up of numerous detailed statements—as the net balance resulting from a year's vouchers of a treasurer, or a year's account in a bank ledger—it is obvious that it would often be practically out of the question to apply the present principle of requiring the production of the entire mass of documents and entries to be perused by the jury, or read aloud to them, the convenience of trials demands that other evidence be allowed to be offered in the shape of the testimony of a competent witness who has perused the entire mass, and will state summarily the net result. Such practice is well established to be proper. Most courts require as a condition that the mass thus summarily testified to shall, *if the occasion seems to require it*, be placed at hand in court, or *at least be made accessible to the opposing party, in order that the correctness of the evidence may be tested by inspection, if*

desired, or that the material for cross-examination may be available."

Wigmore on Evidence, Vol. 2, Sec. 1230.

In Ritter vs. State, 69 S. W., 262, an expert accountant was allowed to testify to the shortage of defendant, as shown in voluminous bank books.

In the case of San Pedro Land Co. vs. Reynolds, 121 Cal., 74, the production of books was excused when the original consisted of numerous accounts or other documents which could not be examined in court without great loss of time, and the evidence sought from them is only a general result of the whole.

Wigmore on Evidence, Sec. 1230, further states:

"Upon the same principle summaries of official or corporate records might properly be presented, and testimony by one who has examined the records that no record of a specific tenor is there contained, is receivable instead of producing the entire mass for perusal in the court room."

We, therefore, submit that the point raised by defendants, with reference to the admissibility of the testimony of witness Lockridge is not to be considered of any consequence, complainant having properly shown:

1st. Physical inability to introduce the records.

2nd. The absolute uselessness of the records, if introduced.

3rd. By making a tender to produce the books for examination of counsel for defendant, and this, too, without any expressed desire upon the part of defendants' counsel to examine them.

4th. Because defendants' counsel stated at the time that he desired nothing, as the burden of making out the case devolved upon complainant.

From the facts as shown, it will be observed by the court that none of the reasons set forth at law for the rejection of secondary evidence can be made to apply in this case. Complainant is shown not to have attempted to withhold anything from defendants in the way of evidence, or to suppress any statement that might be contained in the records.

> "The rule of evidence does not require the strongest possible evidence of the matter in dispute, but only that no evidence shall be given which, from the nature of the transaction, supposes there is better evidence of the fact attainable by the party. It is said in the books that the ground of the rule is a suspicion of fraud, and if there is better evidence of the fact, which is withheld, a presumption arises that the party has some secret or sinister motive in not producing it. Rules of evidence are adopted for practical purposes in the administration of justice,and must be so applied as to promote the ends for which they are designed.
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> U. S. vs. Reyburn, 6 Pet. (U. S.), 352.
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> "The rule of law is that the best evidence must be given of which the nature of the thing is capable; that is, that no evidence shall be received which presupposes greater evidence behind, in the party's possession or power. The withholding of that better evidence raises a presumption that, if produced, it might not operate in his favor. For this reason a party who is in possession of an original paper, or who has it in his power, is not permitted to give a copy in evidence, or to prove its contents."

Tayloe vs. Riggs, 1 Pet. (U. S.), 591.

"The rules of evidence are adopted for practical purposes in the administration of justice; and, although it is laid down in the books as a general rule that the best evidence the nature of the case will admit of must be given, yet it is not understood that this rule requires the strongest possible assurance of the matter in question. The extent to which the rule is to be pushed, in a case like the present, is governed in some measure by circumstances. If any suspicion hangs over the instrument, or that it is designedly withheld, a more rigid inquiry should be made into the reasons for its non-production. But when there is no such suspicion all that ought to be required is reasonable diligence to obtain the original."

Minor vs. Tillotson, 7 Pet. (U. S.), 99.

"We think that when the very existence of the instrument is denied and the law, in the first place, requires the instrument to be in writing, the diligence shown ought to be of the highest character before secondary evidence of the contents of the lost instrument should be allowed. The danger of the introduction of manufactured evidence is extremely great in such a case, and hence the party seeking to build up a defense upon such an instrument as in this case must use the utmost diligence."

Daly vs. Bernstein, 6 N. Mex., 380; see also
Isley vs. Boon, 109 N. Car., 555.

VI.

IN ORDER TO AUTHORIZE THE INJUNCTION SOUGHT THE ACT COMPLAINED OF NEED ONLY BE SHOWN BY SATISFACTORY EVIDENCE.

Defendants, in their brief and argument, assert that an injunction to restrain a nuisance will issue only in a case where the fact of a nuisance is made out upon determinate and satisfactory evidence. That if the evidence be conflicting and the injury be doubtful, that conflict and doubt will be ground for withholding the injunction, and that where interposition by injunction is sought to restrain, that which is apprehended will create a nuisance of which its complainant may complain, the proof must show such a state of facts as will manifest the danger to be real and immediate.

This proposition of defendants, as stated in their brief, is drawn from the opinion of this court, delivered at the time the demurrer to complainant's bill was overruled.

In defendants' reply to brief and argument of complainant, page 27, the same language is set forth, and a number of cases referred to as authority therefor. It will be observed from the foregoing language it is necessary in order to justify a court in withholding a decree of injunction that the evidence must be conflicting and the injury be doubtful, and that such conflict and such doubt, both considered together, alone constitutes a ground for withholding the injunction.

The fact that the nuisance must be drawn out upon determinate and satisfactory evidence does not, under any circumstances, imply that if the evidence be conflicting the injunction should not be granted, for it is scarcely conceivable that a case

involving the question of the establishment and maintenance of a public or private nuisance could be found whereby all parties conceded the facts involved, and the result of the conduct or actions complained of.

Cases of this sort necessarily imply a conflict of testimony. So the law requires that more shall exist than mere conflict of testimony. There must be a doubt created in the minds of a court as to the correctness of complainant's position as shown by the whole testimony of the case. The question must be determined by the court according to the general rules of evidence, taking into consideration the interest of the respective parties and witnesses, their ability to know and understand the facts about which testimony is being given; the probability or improbability of the truth of such evidence, and its reasonableness.

The principle laid down by defendants, to the effect that an injunction to restrain a nuisance shall issue only in cases where the fact of the nuisance is made out upon determinate and satisfactory evidence, and that if the evidence be conflicting and the injury doubtful that doubt will be ground for withholding the injunction, originated in the action of courts of equity, in granting restraining orders without the regular formalities of a trial, and before the party had been required to have his case tried at law, while the injury was only threatened, or some cases of an early date held that before an injunction can issue unless all the facts and the injury be admitted, no injunction will lie until after trial by jury is had to determine the facts involved.

Under the more modern rule cases of this sort must fall within the ordinary line of equitable litigation, and if it appear by satisfactory evidence that a nuisance has been established, a trespass committed, or a wrong done, and the injury be of

considerable consequence, the court will not hesitate to grant the relief sought.

The practice in this court, as in all equity courts, is that where the injury has not fallen upon the complaining party, but is about to be inflicted, the court must have satisfactory and determinate evidence of the injury. That if the evidence be conflicting and injury doubtful, judgment may be withheld.

The law upon cases of this sort is apparently well settled, and need not be discussed at length. We submit to the court that complainant's testimony shows the establishment of a nuisance, followed by grave and serious injury, and that this injury and danger to the life, health and comfort of complainant's inhabitants is at all times immediate, impending and actually existing.

The evidence shows clearly that deaths from typhoid fever in the city of St. Louis have increased over 77 per cent since the opening of the drainage canal, as compared to a similar period immediately prior thereto. This increase in deaths can be explained in no other way than that it was caused by the conduct of defendants, in the manner complained of in the bill.

In order that there might be no question as to the origin or cause of the increase in typhoid fever deaths at St. Louis, statistics were obtained from the various cities situated upon the Missouri river watershed, the Mississippi river above the mouth of the Illinois and the Illinois river, exclusive of the city of Chicago, for the purpose of determining whether or not typhoid deaths had increased to any material extent which might be attributed as the cause of the increase at St. Louis. The result of this examination was that no material increase was found upon the watersheds of either of the rivers in question. In fact, there seems to have been, in a great number of places examined, considerable reduction in this respect. This data was obtained

covering a period of several years prior to the opening of the canal, and from said opening until the time of taking the testimony herein.

Local conditions at St. Louis were also examined for the purpose of determining, if possible, any local cause for the increase. No such cause having been discovered, attention was then directed, as a last resort, to the opening of the drainage canal as the cause, and the evidence shows that within the proper time of incubation and sickness, considering also the time limit for the germs to travel from Chicago to St. Louis, typhoid fever deaths began to increase in St. Louis, and that such increased mortality has continually existed at all times thereafter.

It is admitted by all of the witnesses who testified in the case from scientific standpoints, and who professed to know of the life history of pathogenic bacteria and the causation of death, so far as water-borne diseases are concerned, that typhoid fever germs, as well as other water-borne pathogenic bacteria, lived in water for a considerable time, the exact duration of life being to some extent uncertain.

From all of the testimony no one can undertake to say that a life limit of less than twenty-five to thirty days for typhoid fever germs can be adopted with such assurance as would guarantee the promiscuous use of water into which they had been previously deposited, without likelihood of contracting the disease.

While it is true a number of lay witnesses residing upon the banks of the Illinois river, and living in boat-houses, testified that the water in the Illinois river since the opening of the drainage canal had become more inviting in appearance than it was prior thereto—that before the 17th day of January, 1900, the water of the river, from one end to the other, was covered with

a green scum throughout the greater part of the year; that it was practically without current; that since the 17th day of January, 1900, there had been a continuous current, and that this green algae formation had disappeared entirely, yet these witnesses, mostly fishermen, who were accustomed to river life and the use of river water, testified that the water was not for domestic purposes. Occasionally one would make the statement that if caught without water, he would drink it, with no bad results following. The business men and physicians residing in the smaller towns upon the river testified that the water was not being used for domestic purposes, although from its physical appearance it was observed to be in much better condition than prior to the opening of the canal.

The city of Peoria abandoned the Illinois river as a water supply shortly before the canal was opened. This was the last city to take its water from the river, and since the canal had been opened no municipality has used the water for domestic purposes.

Our contention is, and it is supported by all the expert testimony in the case, that while the water of the river, on account of the added volume from Lake Michigan, may appear to be in better condition since January 17, 1900, than prior thereto, yet there can be no question but that more infectious material exists in it now than prior to the opening of the canal. The same sources of infection and pollution exist today as then, with the addition of the infectious material coming from the city of Chicago, and the immense population of the sanitary district. Not only is this large quantity of infectious material still being deposited into the Illinois river, but on account of the added volume of water the facilities for self-purification have become so greatly reduced as to preserve and promote the life, vitality and special resistant forces of all pathogenic bacteria.

Prior to the opening of the canal pathogenic bacteria reaching the water from the natural drainage area of the river remained in a quiescent condition, often times stagnant, which was conducive to the destruction and disappearance of pathogenic bacteria. Since the opening of the canal these conditions have not pertained, the water flowing continuously, with a strong current, from lake to river, carrying the disease producing organisms in its flow, with but little opportunity afforded for self-purification, putrefaction or decay. These disease producing germs are pushed more rapidly towards the Mississippi river now than before, and when the sewage of Chicago is added thereto, creates an additional menace to the people of Missouri; constitutes an unpardonable offense against complainant, injurious to the health and comfort of its inhabitants, and causing, as before stated, an increase of about eighty per cent in deaths from water-borne diseases in the city of St. Louis.

It is true that considerable of the chemical and bacterial data obtained by defendants upon the condition of the water of the Illinois river prior to and subsequent to the opening of the drainage canal shows some reduction in the number of bacteria found, or the quantity of chemical compounds found in given quantities of water. An examination of these plats, tables and analyses will show, however, that there has not been the reduction contended for by defendants. The volume of water has been increased about fifty per cent. The reduction of chemicals and bacteria on account of dilution should be at least fifty per cent. The reduction in chlorines, which is an indestructible substance, shows the extent of the dilution which has taken place. This reduction, in a great many instances, is found to be as much as fifty per cent, while substances such as free ammonia, albuminoid ammonia, total solids, suspended matter, nitrites and nitrates are shown to have been reduced only slightly, and in

many instances have in reality increased. With the added volume of water, and with all chemical substances passing down stream uniformly and at a more rapid rate since the opening of the canal than prior thereto, it would naturally be expected that these substances would be found to be much less in quantity and their percentage now, as compared to a time prior to the opening of the canal, would be very greatly reduced. This fact, considered along with the proposition that all the chemical and bacterial data of complainant shows an increase in polluting and infectious matter in the waters of the river since the opening of the drainage canal—which showing is in harmony with reason, and nature—it can not be said that the testimony of complainant and the opinion of its expert witnesses is to be defeated because defendants' witnesses have undertaken to express a contrary view. The fact is, and the court will so observe from reading the testimony of defendants' professional witnesses, that their opinions are not warranted by the evidence introduced in the case—not even their own chemical and bacterial data.

The opinion expressed by defendants' scientists as to the disappearance of pathogenic bacteria in the Mississippi river is shown to be a mere arbitrarily selected standard, without regard to natural conditions in the river, and without regard to past experience of sanitary scientists in passing upon the potability of water. Certainly, then, simply because defendants have seen proper to introduce in evidence the opinions of professional men in conflict with the opinion of complainant's scientists, and in conflict with the experience of mankind, as well as contrary to the laws of nature, well knowing that the exact life of all pathogenic bacteria had as yet not been determined, and well knowing that each particular pathogenic organism depended upon special environments, and inherent resistant forces for its life

and vitality, that some germs live much longer than others, even though they be of the same class or species, and that it is beyond the power of the human hand or brain to make an accurate determination as to just how long they will live under all circumstances in nature and in a running stream, and knowing also that there has been an increase in typhoid fever deaths in the city of St. Louis since the opening of the drainage canal, attributable to no other cause than such opening, defendants can not expect to ask this court to hold that the opinion of such witnesses preponderates over the entire testimony in the case and the opinion of complainant's witnesses; which latter opinions are entirely consistent with every word of the testimony, and with the ordinary understanding of mankind, so far as the longevity of pathogenic bacteria in water is concerned.

This brief statement, in the main, supported as it is by all of the testimony in the case, shows clearly that the act and conduct of defendants sought hereby to be restrained, constitute a substantial injury to complainant, and that the danger thereby created is at all times imminent.

All that is necessary, all that courts or defendants can reasonably ask, is that complainant make out a clear case, showing the injury inflicted or the injury impending and about to fall. With such showing relief is always granted.

Lambert vs. Lewinski, 47 Ill., 656.
Owen vs. Phillips, 73 Ind., 284.
Mirkil vs. Morgan, 134 Pa. St., 144.
Halsman vs. Boiling Spring, 14 N. J. Eq., 335.
Rowell vs. Bentley, 34 W. Va., 804.

Where a nuisance is permanent, continuous or constantly recurring, legal remedy is obviously inadequate, and the interference of a court of equity is necessary to prevent irreparable injury or a multiplicity of suits.

Niginer vs. Norwood, 72 Ala., 277.
Hamilton vs. Whiteridge, 11 Md., 128.

Where a city emptied sewage on plaintiff's land, thereby rendering his building unfit for habitation, it was held that he was not obliged to bring an action at law to abate the nuisance, but was entitled to an injunction.

Bates vs. Elmira, 22 Hun., 158.

Looking particularly at the facts in the case which warrant the court in granting the injunction and fully justify complainant's conduct in bringing this suit, the following constitute the position in which defendants are placed:

1st. Defendants admit discharging pathogenic or disease producing bacteria into the canal, and admit, of course, that the water from the canal passes into the Desplaines and thence into the Illinois and Mississippi rivers.

2nd. Admit that a large volume of water is added to the water of the Illinois river by means of the canal. This added volume equals at times the entire volume which passed down the river prior to the opening of the canal. This increased volume, according to the testimony of complainant's witnesses, prolongs and preserves the life of pathogenic bacteria.

3rd. Admit the exact longevity of pathogenic bacteria in a running stream can not be determined.

4th. The foregoing facts having been established, by practically undisputed evidence, defendants attempt to convince the court that all of the pathogenic bacteria coming from the city of Chicago have perished or disappeared within three or four days after being discharged into the canal. This attempted proof is based solely upon the opinions of witnesses, whose opinions are shown to be in direct conflict with the actual facts

in evidence, and not warranted from the statements of the witnesses themselves as to the ability of pathogenic bacteria to live and travel for days and miles in the waters of a running stream. This is apparent from the evidence in part, as follows:

Prof. Barker, one of defendants' witnesses, testified upon the facts here involved as follows: In speaking of conditions at Toronto, Canada, and the source of its water supply, in his opinion, the intake of the Toronto supply, in order to guarantee freedom from contamination by Toronto sewage, must necessarily be extended into Lake Ontario, a distance of about 100 miles; the witness evidently not realizing that such distance would carry the extension far into the State of New York.

The above statement verifies complainant's position in this, that if pathogenic bacteria can be carried out into a lake to a distance of 100 miles, and still be capable of producing disease when drawn back into the water supply, how much more reasonable is it to believe that they may be carried by a running stream a distance of 350 miles. Especially is this true when the distance traveled falls within the lifetime of the germ. In other words, in a body of water practically quiescent, it would require a longer time for the germs to reach a given point than it would if deposited into the current of a stream. (Barker's testimony, Record, pp. 7119-20-21.)

Further on Prof. Barker was asked this question:

> "Q. Do you mean to class yourself as an epidemiologist when you say that typhoid fever germs will live in the Missouri, Mississippi and Illinois rivers only for from five to seven days?
>
> "A. I did not say that. I did not say that they had lived in those rivers only from five to seven days.
>
> "Q. How long did you say they would live?
>
> "A. I did not say how long they would live.

"Q. How long will they live?

"A. I do not know; nor is there any way at present of finding out." (Barker's Testimony, Record, p. 7131.)

"Q. Do you teach your students that typhoid fever germs will die in from five to seven days?

"A. I haven't taught students bacteriology for sometime, but if I were teaching them now I would not teach them that they would die in five to seven days. I have not said so.

"Q. Will they die in five to ten days?

"A. I said I thought that in all probability in sewage they would largely die out before ten days. (Barker's testimony, Record p. 7132.)

"Q. Do you think there is enough sewage goes down to Grafton to kill typhoid germs?

"A. Which typhoid germs?

"Q. That are deposited in the water at Chicago, in the river at Chicago.

"A. I am not sure that any typhoid germs get as far as Grafton from Chicago.

"Q. Well, do you think that they do not?

"A. I do not think they do. I do not think anybody could say they do not. My opinion is they do not.

"Q. Well, now, on what do you base that opinion? You say they do not—your opinion is they do not?

"A. I did not say that they do not, because I do not think anybody can say that, but my opinion is that they do not. (Barker's testimony, Record pp. 7144-45.)

Upon the question of the life of typhoid germs in sewage contaminated water it is important to remember that a great

many reputable scientists are of the opinion that these germs live perhaps as long in sewage contaminated water as in water in its natural condition. The reason given by them for its not being found in sewage polluted water is that the ordinary sewage bacteria, commonly known as saprophytes, overgrow the parasites to such an extent that they cannot be found upon the plates used in making the determination. This is termed by experimenter as "masking," so that the saprophytes mask the parasites to such an extent as to keep them from being discovered by the observer. All scientists, however, agree that masking to a certain extent takes place, and that it is much more difficult to carry on observations of typhoid germs in sewage polluted water than in ordinary water. Dr. Barker, in this connection, testified:

> "Q. In other words, Doctor, don't you know this, that they die out just as quickly in ordinary, safe drinking water as they do in sewage polluted water, and the difference in distinguishing the duration of life in the two experiments is caused by the great increase of growth of the saprophytic bacteria in the sewage polluted water, so it has a tendency to cause saprophytes to overgrow and render conditions such that you cannot discern typhoid because of their failure to multiply?
>
> "A. Well, it is obvious that there could be two interpretations of the results of such experiments. One interpretation would be this; the other would be the one that I put upon it. I think both opinions are held. It is obvious that one could not say which was right when the doctors disagree." (Barker's testimony, Record pp. 7147-48.)

Dr. Barker further testified that the more water you put into the canal at Chicago the greater the danger is increased lower down the Illinois river; and that if there is more water coming out of the river at Grafton than there was prior to the opening of the canal, the danger would be increased at that point. (Barker's testimony, Record p. 7150.)

Defendants rely largely upon the statement of Prof. Zeit, in which he undertakes to fix a positive point on the Illinois river as the zone of purification, or that point in the river at which all of the pathogenic bacteria coming from the city of Chicago may be said to have entirely disappeared or perished. Dr. Barker, in speaking of this imaginary point, stated that it was a vague point—"of course, we have no means of determining," and when asked why it was vague, replied, "Because our information is not definite enough to permit us to locate it." (Barker's testimony, Record p. 7151.)

In speaking of the condition of the water of the Mississippi river at St. Louis, and the effect of the sewage of Chicago upon it alone, Dr. Barker stated that he would not recommend it at Grafton nor at New Orleans, after removing all source of pollution other than Chicago, although he thought it would be safe. In this connection he was asked this question:

> "Q. Well, if you think it would be safe, why are you not willing to recommend it?
>
> "A. Because we have ways of making it absolutely sure. My opinion on safety is an opinion. We have methods of being absolutely sure about our drinking water." (Barker's testimony, Record p. 7155.)

Dr. Barker also stated that the best test to be applied for recommending the use of water for drinking and domestic purposes was the experience of the people who use it, and ascer-

taining whether or not typhoid existed among them; and also to ascertain whether or not there were other opportunities for typhoid infection of the people. "This is the best and only sure test." (Barker's testimony, Record p. 7158-59.)

"Q. It is your opinion, is it Doctor, that the sewage from Chicago, with two millions of people, has no effect in rendering the water flowing down the Illinois river unsanitary from source to mouth?

"A. No, I have not said anything like that. I am sure I have never said anything like that.

"Q. It is your judgment, then, that it has no effect on it at its mouth?

"A. You mean at Grafton?

"Q. At Grafton.

"A. In my opinion, the effect would not be appreciable.

"Q. Do you know how many people live on the Illinois river between Lockport and Grafton?

"A. I do not.

"Q. Do you know how many people live on the whole watershed tributary to the Illinois river, between those two points, exclusive of the city of Chicago?

"A. No.

"Q. Now, then, exclude Chicago and the sewage therefrom from the Illinois river, would you recommend the water of that river at Grafton for domestic and drinking purposes in its present condition?

"A. I think it would be tolerably safe to use, but I would not recommend it.

"Q. Why would you not recommend it?

"A. Because I would want to make tests and find out whether it was really pure or not.

"Q. Tests for what?

"A. Tests especially for the presence of typhoid bacilli, as shown by the occurring of cases among people who drink of the water.

"Q. If you knew that there were 100 cases of typhoid fever during the months of May, June, July, August and September in the city of Chicago, would you use the water of the Illinois river at Grafton for drinking and domestic purposes?

"A. I would boil it until we have more knowledge. I think it would be safe, but I would boil it until we had more knowledge about it, boil it or filter it.

"Q. I will ask you this, if your reason for saying that you would boil it is because of the uncertainty of ascertaining just how far the germs will travel—how long they will live, and because of the fact that science has been unable to determine the length of life and the distance they will travel, and the conditions under which they live in a running stream?

"A. My answer to that is that I always use the most perfect method whenever I can in technique.

"Q. Anything then, added to the character of the water, in the way of creating a suspicion, and in the way of creating a deleterious effect upon the water in giving an opportunity for the presence of disease producing germs, would render that water less valuable for domestic and drinking purposes, would it not?

"A. You mean commercially?

"Q. Financially, commercially, sanitarily and every other way in which water is used.

"A. Exactly in the degree in which the suspicion was believed to be well founded.

"Q. How long do you think typhoid germs will live in a running stream?

"A. Under what conditions?

"Q. In ordinary river water?

"A. Without any special sewage contamination?

"Q. Without any special sewage contamination.

"A. I do not know how long they will live.

"Q. You have no idea upon the subject?

"A. Well, I should think it would be only a case—it would be a mere opinion, but I should think that they would or might live as long as ten days. I do not think they would live longer than thirty days." (Barker's testimony, Record pp. 7165-66-67.)

Again Dr. Barker stated that he did not care to express an opinion as to how long typhoid germs would live in the Illinois river; that his opinion would be an indefinite one, and this question was asked him:

"Q. They might live five days and they might live thirty days?

"A. I do not think they would live more than thirty days. I do not think in the Illinois river they would live that long, if they started in at the upper part of the river." (Barker's testimony, Record p. 7169.)

From the testimony of Prof. Burrell, also a witness for defendants, it will be found that the same general uncertainties exist with reference to the longevity of pathogenic bacteria, and especially of typhoid germs; and that one of the principal rea-

sons why it is believed they perish in sewage contaminated water at an early day is the result of what has heretofore been termed the masking of the saprophytes; that the life of pathogenic bacteria depends largely upon the resistant forces of each particular germ, and therefore it is impossible to determine the exact point in a river where the water would become relieved of pathogenic bacteria deposited in it at a point above. Certainly this could not be done if sufficient attention is given to the word "exactness." (Burrell's testimony, pp. 5780-81 and 84.)

At page 7029 of the printed record, Mr. Rudolph Herring, also a witness for the defendant, and the sanitary engineer who devised the scheme of building the drainage canal and constructing the dam at Lockport, was asked this question with reference to the longevity of typhoid fever germs:

> "Q. Mr. Herring, is there any instance in your whole career as a sanitary engineer, or an instance coming under your observation as to the work of other reputable sanitary engineers or sanitary scientists, where the water in a running stream has been recommended as free from typhoid bacilli of a large and populous city existing on that watershed with a stream velocity of from ten to twenty days?
>
> "A. *Without filtration, I do not know of any case exactly answering your description.*

In speaking of the disappearance of pathogenic bacteria in running water, Mr. Hill, a witness for the defendants, at pages 7572-73-74, stated that the waters of the Schuylkill river at Philadelphia were more highly polluted than the Illinois, and that he had observed typhoid germs to live in the waters of the Schuylkill for a period of from six to eight days. Then this question was asked:

"Q. Mr. Hill, then would you recommend the waters of the Delaware and Schuylkill after it had passed down the stream for eight days from the time the typhoid infecting material was discharged into it and it received no additional infecting material, as being free from typhoid fever germs?

"A. I believe that it would.

"Q. Would you recommend it for domestic purposes, as being free from typhoid fever germs?

"A. No, I would not, because there are other things than typhoid fever organisms, other pathogenic bacteria."

The fact that the life of typhoid fever germs, as well as of other pathogenic bacteria is uncertain; not capable of being measured by any formula heretofore devised, and varies according to the special environments of the respective germ, together with the special forces of vitality which pertain to each is emphasized by the testimony of Prof. Jordan, on behalf of defendants. See Jordan's testimony, Record pp. 6343 to 6399, inc.

Prof. Mason, another of defendants' witnesses, at page 6960-61, makes this statement:

"My opinion is that in considering the facts regarding the Chicago sewage being dumped into the Illinois river, as at present, and the facts concerning the conditions of the Illinois river that the germ of typhoid fever coming from Chicago sewers would be destroyed en masse by the time the mouth of the Illinois river was reached, although some resistant organisms might go beyond that point."

Again, on page 6974, this question was asked of Prof. Mason:

"Q. Professor, is it not a fact that the longevity of the typhoid fever germ, as well as all other pathogenic bacteria, in all the various conditions in nature, taking into consideration climatic influences and all of the elements which affect the vitality of those organisms, scientists have been unable thus far to formulate any rule or formula by which the longevity of the germs may be measured within certain accurately defined limits?

"A. Scientists have thus far been able to determine the longevity of pathogenic germs only within roughly accurate limits."

Again Prof. Mason said:

"My opinion is that it is impossible to tell what shall be the longevity of specially resistant cells. Experimental data have shown that, for the general mass, the longevity is fairly well fixed, so that a good deal of knowledge has been obtained with reference to the average germ, although we are still in ignorance as to the longevity of specially resistant individuals." (Record, p. 6961.)

Prof. Russell, a witness for the defendants, testified in this connection, as follows:

"I do not consider that the data given with reference to the longevity of the organism" (meaning typhoid fever bacilli) "could be expressed in terms with mathematical accuracy, and if it were so expressed it would be necessary to take into consideration the effect of these factors mentioned, that the typhoid organism is subject to the influence of these variable factors, and

that these might change the rate of destruction, and in setting such a limit it must be placed at such a point as in the judgment of the investigator will be sufficient to permit of the operation of all of these factors referred to, and effect the destruction of all organisms of the class concerned."

The above statement was made by Prof. Russell in answer to the following question:

> "Q. The conditions of moisture in the soil, the character of the sediment, the character and extent of pollution, the extent of dilution are so variable no rule or formula could be adopted by which the life of the typhoid germ, under these various conditions, might be accurately observed without taking into consideration the degree of variation that exists in the longevity of the various germs themselves. That is, the extent of their virility, their hardiness and robustness, as compared with each other." (Record, pp. 6587-88.)

Again, in speaking of the effect of the water from Lake Michigan upon the sewage of Chicago, in that it prevents great concentration of sewagic material, Prof. Russell said:

> "When the degree of concentration is at such a point as to just be able to destroy the typhoid organism in a given period of time, manifestly, the dilution of that degree of sewage concentration with water which would reduce the amount of prejudicial substances, would permit of the retention of the vitality of the typhoid organism for a long period of time." (Record, p. 6591.)

In speaking of the value of the experiments carried on by himself, Prof. Zeit and Prof. Jordan, in which parchment sacs were employed, Prof. Russell, at p. 6598 of Record, stated as follows:

> "The water which was used in the making of these experiments was taken from the river at approximately the point where the sacs were immersed. In as much as the germ content of a flowing stream is subject to fluctuations, depending upon the amount of sediment and numerous other factors which modify the germ life found in a given body of water, the sample of water placed in the sac *would not and could not, under any condition, be exactly the same in germ content as was the case in the water flowing past these sacs for the period of time covered by the experiment.*"

It will be noticed by reading the testimony of Prof. Zeit, Prof. Jordan and Prof. Russell, upon the result of their experiments with typhoid fever germs deposited in parchment sacs and suspended in the waters of the Illinois river and the drainage canal, it is shown conclusively that natural conditions were by no means assimilated; that the germs contained in the sacs were not allowed to pass down the river continuously with the water, and thereby become relieved of the gradual reduction in saprophytic bacteria. In fact, as shown by the testimony of Dr. Herbert E. Smith, Prof. Sedgwick and Mr. Lockridge, the variation from natural conditions is apparent for numerous reasons.

Although not assimilating the natural conditions which have a tendency to prolong the life of the organism, the proof shows the germs of typhoid to have been kept alive in these sacs for a period of ten days. This disclosure was made regardless of the fact that no extensive research was undertaken, the observers

evidently satisfying themselves as to the disappearance of the germ by observing a few colonies upon each particular plate examined.

An attempt is made by each of these experts to discredit the result of their own determinations, by attacking the genuineness of the disclosure on the tenth day.

They were doubtless persuaded to do this because if compelled to admit the discovery on the tenth day, to be at all natural and genuine, the opinions expressed by them with reference to the longevity of the germ and its ability to pass from Chicago to St. Louis would at once become totally discredited.

In view of the fact that well known observers of world wide reputation have, as shown by all of the testimony in the case, found these germs alive in sewage, and in water highly contaminated with sewage, for a period longer than ten days, the opinons of these witnesses, based as they are upon the observations made by them, cannot be relied upon. They must be regarded, if at all, as mere exceptions to the general rule and the general line of observations of this sort. More particularly is this true when we take into consideration the fact that all of the witnesses admitted that exact natural conditions were not assimilated, and the statement of Prof. Russell "That these experiments do not and could not, under any condition, be exactly the same in germ contents as was the case when the water was flowing past the sacs covered by the experiment."

In speaking of the diluting effect of the Lake water upon the contents of the drainage canal and the Illinois river, Prof. E. G. Smith, for defendants, at p. 6830, said:

> "The influence of dilution by the Lake water tends to dilute sewage matter placed in the river, and in so far tends to the prolongation of the life of the bac-

> teria. * * * The introduction of this amount of water would tend to increase the speed of the current, and therefore tend to push the pathogenic bacteria further down the river than they would prior to the opening of the canal."

In speaking about the longevity of typhoid fever germs, Prof. E. G. Smith, at page 6831, further said:

> "It is true that different strains, as they are termed, of typhoid fever organisms possess a different degree of resistance to destructive agencies."

This statement, although made on behalf of defendants, is borne out by all of the testimony in the case, it being conclusively established, as hereinbefore stated, that some germs of typhoid are unquestionably of greater vitality than others, regardless of the fact that they may come from a common source.

It is also shown, and as an undisputed fact, that germs of typhoid, resulting from a distinct case of typhoid fever, may be more highly vitalized than those coming from other cases. In other words, there is a variation in the life and vitality of the germs, both as to the source from which they come and as regards the special vitality powers of each of the germs compared with one another, regardless of the source.

At page 4652, Prof. Zeit, a witness for defendants, was asked this question:

> "Then I understand you to say, Professor, that it had not been determined, and could not be determined, from a bacterial standpoint, just what effect the changes taking place in the water by the removal of old and the addition of new would have upon the bac-

terial conduct of the water or the operation of the water on the life of the typhoid germs in that water.

"A. That is correct. I will admit that it would probably live longer if these saprophytic products were not present or were capable of being removed. As to the time, I think it has never been determined by anyone what the difference would be between the laboratory experiments and the actual experiments in the river water.

"Q. That is, under the actual conditions of the water?

"A. Under the exact conditions of the water, that has not been determined."

The foregoing statement, made by Prof. Zeit, is based upon the fact that in the laboratory experiments the germs are confined in a test tube and are consequently unable to relieve themselves from the bad effect of the toxic products which they create, while in a running stream the toxic products pass away, or the bacteria, being mortal, seek a more comfortable position.

The above proposition is sufficient to corroborate the general rule that anything possessing life will live longer if given an opportunity to assert its liberty, rather than if put in the position of a prisoner, with no opportunity to protect itself from the injurious results of its environments.

However, regardless of whatever position may be taken in this respect, the true history of the life of pathogenic bacteria in a running stream has not and can not be measured or determined only within anything that approaches satisfactory and indefinite limits. We refer particularly to the testimony of Prof. Zeit, as shown by the Record at the following pages: 4590, 4604, 4605, 4616, 4621, 4691, 4695, 4730.

We call attention in this connection to the testimony of complainant's witnesses to the effect that conditions in the Illinois river are such that typhoid fever bacteria do pass from Chicago to St. Louis and produce typhoid fever among the people of the latter city using the water for domestic purposes. The testimony to the above effect is clear, distinct and reasonable. The opinions expressed by witnesses for complainant are not only based upon facts introduced in evidence, but also represent the prevailing idea of sanitary scientists.

(Whipple's testimony, pp. 1996-7-8-9, 2003; Sedgwick, 2188 to 2241, and 7954 to 7960; Williams', 2463; Fuller, 2607 to 2624; Herbert E. Smith, 7685 to 7696, and 7609 to 7716, and 7755 to 7760.)

As an evidence of the great straits which defendants' expert witnesses believed themselves to confront, a condition, no doubt, which warranted many of the extravagant statements made by them (statements contrary to reason, rational belief and the experience of prominent observers, and which from the effects of the opening of the canal upon the health of the city of St. Louis are not to be relied upon), we call attention to the following statement made by Prof. Zeit, at page 4691 of the record:

> "All the typhoid bacilli that are produced by all the typhoid cases in Chicago, if they were all turned into the river, and if they were not exposed to any conditions whatever of destruction, and if they all arrived at the Mississippi at that locality, they would be so far distributed and so diluted through the immense amount of water that the number of them would be inappreciable, and that it would be a grave question whether any of them, even one, would enter the inlet at the Chain of Rocks."

The impracticability and unreasonableness of this statement is apparent. The city of Chicago alone has a population of two millions of people, while the entire urban population, exclusive of Chicago, on the Illinois, Mississippi and Missouri rivers is only 2,695,000. There can be no question but that the population residing upon the watershed of a stream is largely the cause of typhoid fever among those people living lower down and who use the water of the stream for domestic purposes. This statement conforms with the experience of mankind.

That the citizens of St. Louis have for years suffered with typhoid fever can not be questioned, and that a great portion of it comes from its water supply is likewise true. So, to state that the sewage disposal of two millions of people discharged into the Mississippi river, at a point immediately above the intake at the Chain of Rocks, would become so diluted as to render altogether unlikely the passage of any germs of typhoid into the intake of the St. Louis water supply, is altogether too reckless and unreasonable for belief. Having made this statement, doubtless the witness, as in the case of the other witnesses for defendant, was largely influenced by the question of dilution in expressing an opinion as to the effect of the sewage of Chicago upon the people of St. Louis. And so relying upon the question of dilution, disregarded the well known and established facts which pertain to the longevity of pathogenic bacteria in water.

Considering the foregoing testimony along with that of complainant to the effect that typhoid fever germs have been found to live in sewage infected water for many weeks, and in reasonably pure water for several months; that such determinations are in accordance with the judgment and experience of all persons having to do with sanitary science, and constitute the basis upon which water supplies are recommended and filtration

plants established, it is apparent that any adverse opinions expressed by witnesses on behalf of defendants are inconsistent with actual facts, and therefore are based upon imaginary premises, unwarranted by any investigation made for the particular purposes of this case, as well as unwarranted by the experience of the sciences of bacteriology, chemistry and epidemiology.

Aside from any opinion that may have been expressed by any witness in the case as to the ability of typhoid fever to pass from Chicago to St. Louis, we now call the court's attention to the evidence which shows an increase of nearly eighty per cent in deaths from typhoid fever in St. Louis since the opening of the drainage canal, as compared with conditions immediately prior thereto. The evidence of complainant in this behalf is clear, conclusive and convincing.

Defendants made an effort to discredit the proof of complainant to the above effect. After ingeniously examining and criticising the published health reports, they were compelled to admit that an actual increase in typhoid fever at St. Louis had occurred since the opening of the drainage canal, as compared to the time immediately prior thereto. This increase is shown according to defendants' own testimony and explanation of the published health reports, conceding that every word and figure contained in the health reports be as explained and criticised by defendants' witnesses.

At page 7076, Dr. Dock, in speaking of the mortality records of the city of St. Louis for the years 1896 to 1903, inclusive, and in commenting upon the fact that the column set out in said reports for typhoid fever did not contain all of the deaths from typhoid, for the reason that a great number of typhoid deaths had unquestionably occurred that had been recorded under the head of malaria, intermittent, remittent fevers, etc. This witness, in this connection, testified as follows:

"Doctor, confining yourself to the four years preceding, and the four years subsequent to the opening of the drainage canal, I will ask you if there has not been tables introduced by you or Prof. Jordan, and referred to by you in your examination which show an increase in typhoid fever in the city of St. Louis?

"A. There has been an increase.

"Q. Even though you transfer all remittent, intermittent, congestive, etc., fevers into the typhoid column?

"A. There has been an increase, yes, sir.

"Q. Based upon the number of cases per 100,000 of population?

"A. Yes, sir."

The above statement shows that in the judgment of this expert there has been an increase in typhoid fever at St. Louis. More particularly is this shown when we take into consideration that all the physicians who attempted to criticise the Board of Health reports of St. Louis, admitted that a great number of deaths reported under the columns intermittent, remittent, etc., fevers, were acurately reported. However, transferring all of those cases into the typhoid column, the result still shows an increase as above stated.

We now call attention to the testimony of Mr. E. E. Lockridge, who on behalf of complainant, made a personal examination of the mortuary records of St. Louis, for the purpose of determining the correctness of the evidence of Prof. Jordan, Dr. Barker and others on behalf of defendants concerning this proposition.

Mr. Lochridge testified substantially as follows:

That the deaths reported from remittent fever for the years 1896 to 1903, inclusive, were as follows:

1896, 40 deaths.
1897, 29 deaths.
1898, 26 deaths.
1899, 15 deaths.
1900, 15 deaths.
1901, 23 deaths.
1902, 17 deaths.
1903, 17 deaths.

Showing no perceptible change in the mortality from this cause.

Deaths from intermittent fever for the respective years were as follows:

1896, 12 deaths.
1897, 12 deaths.
1898, 16 deaths.
1899, 25 deaths.
1900, 10 deaths.
1901, 12 deaths.
1902, 9 deaths.
1903, 11 deaths.

Deaths from congestive fevers were reported for the respective years 1896 to 1903, inclusive, as follows: 16, 12, 13, 15, 15, 14, 15 and 17, respectively.

Malarial fever deaths for the same period were, 27, 34, 23, 35, 40, 28, 38 and 33, respectively.

"Q. State whether or not you have read the testimony introduced in evidence by Dr. Barker and Prof. Jordan.

"A. I have.

"Q. Did you examine the tables of typhoid statistics for St. Louis, prepared and introduced by him, and which now form a part of the evidence of defendants in this case?

"A. I have.

"Q. I will ask you to state whether or not any of the deaths from fevers known as intermittent, remittent, congestive and typho-malarial and continued fevers for the years 1896 to 1903, inclusive, or all of them taken together, correspond in number with the numbers given by Dr. Baker and Prof. Jordan, according to the tables of typhoid statistics from St. Louis, as introduced by them.

"A. Adding together the deaths which I found in the study of the records at the mortuary office for remittent, intermittent, typho-malarial, congestive and continued fevers, I find that for the years 1896 to 1899, inclusive, there were respectively 120, 106, 85 and 86 deaths, and that if the number of deaths which I found in the records in the mortuary office from malaria are added to those there are in these years respectively 156, 140, 108 and 121 deaths, while Prof. Jordan gave for the corresponding years 177, 172, 134 and 148. The number of deaths which I found recorded on the books in the mortuary office from these causes is a little lower in each year than the list taken by Prof. Jordan from the printed health report.

"In the four years from 1900 to 1903, inclusive, adding together the deaths which I found in the books in the mortuary office in the city of St. Louis from remittent, intermittent, typho-malaria, congestive and

continued fevers, I find for these years 77, 62, 76 and 73. Adding to these the deaths which I find of malaria fever for the years, there were 137, 90, 114 and 126, or a little higher in each year than those given by Prof. Jordan.

"Q. State whether or not there is considerable difference between the data compiled by Prof. Jordan and adopted by Dr. Barker, and that ascertained by you, from your examination of the mortuary records in the Health Department of St. Louis, and state wherein the difference lies.

"A. Considering the fact that malarial fevers were in all probability recorded in this list, as they do not occur under any other caption, so far as could be discovered in the printed health reports, I find that Prof. Jordan has in his list 21 more deaths in '96, 32 more deaths in '97, 26 more deaths in '98, 27 more deaths in '99, 25 less in 1900, 10 less in 1901, 12 less in 1902 and 35 less in 1903 than I found in my study of the records in the mortuary office in St. Louis." (Record pp. 7837, 7838.)

The witness then testified that he had also, in his examination of the mortuary records, included deaths attributable by the attending physician to bilious fever, enteric fever and deaths in which typhoid was assigned as the cause, and also typhoid-pneumonia deaths.

It will be remembered that witnesses Jordan, Barker and Dock testified that the deaths reported as bilious fever, enteric fever and deaths in which typhoid was the cause, and not included under other causes, and typhoid-pneumonia deaths were in reality largely typhoid deaths, and should be so included.

According to Mr. Lockridge's testimony, there was during

the respective years from 1896 to 1903, inclusive, the following deaths reported from bilious fever: 11, 8, 3, 6, 3, 5, 7, 7. Enteric fever: 0, 1, 3, 2, 2, 2, 2 and 0. Deaths in which typhoid was a cause, not included in other table: 0, 1, 1, 1, 0, 2, 3, 8. Typho-pneumonia deaths: 13, 18, 17, 14, 9, 18, 25, 26. (Lockridge's testimony, Record pp. 7839-7844.)

In his examination of the mortuary records Mr. Lockridge found the following deaths reported from typhoid fever during the respective years from 1896 to 1903, inclusive:

1896, 101.
1897, 114.
1898, 90.
1899, 121.
1900, 154.
1901, 181.
1902, 216.
1903, 281.

Thus showing the increase complained of by the State of Missouri.

As stated in our original brief, the grand total of all deaths from remittent fever, intermittent fever, typho-malaria, congestive, continued, malarial, bilious, enteric, and deaths in which typhoid was the cause, and not included in other tables, and typhoid-pneumonia, as shown by the testimony of Mr. Lockridge, are as follows:

1896, 180.
1897, 168.
1898, 134.
1899, 144.
1900, 131.

1901, 117.
1902, 141.
1903, 167.

The average number of deaths from typhoid fever occuring at St. Louis for the four years prior to the opening of the canal was 106.5 per annum, and the average number per annum for the four years since the opening of the canal was 208, or an increase of 101.5 during the whole period.

The number of deaths reported from intermittent, etc., fevers, was 156.5, during the period from 1896 to 1899 inclusive, and 140 per annum for the years 1900 to 1903 inclusive. Admitting that some deaths reported as intermittent, remittent, etc., fevers were in reality typhoid, and thereby reducing the typhoid increase at St. Louis of 101.5 per annum by the apparent loss or decrease in remittent, etc., fevers of 16.5 deaths per annum, we attain, on the basis of defendants' calculation an annual increase of 85 deaths from typhoid fever, or a percentage increase upon the total mortality of the city from typhoid of a fraction over eighty per cent. annually, thus conclusively showing that there has been a material increase in deaths from typhoid fever at St. Louis since the opening of the drainage canal. In view of the fact that every possible effort has been made to ascertain the true cause of the increase and that the entire watershed of the Mississippi river above St. Louis has been carefully investigated and thoroughly inquired into by competent witnesses upon both sides, we conclude that beyond a reasonable doubt the opening of the drainage canal is the cause of such increase. And this conclusion is verified not only by the admitted fact that typhoid fever germs live in running water, that their duraton of life is yet an unknown question, but also, by the fact that no conceivable cause other than the sewage of Chicage could have infected the water at St. Louis to such an

extent as to produce a constant, continuous and never ceasing increase in cases of and deaths from typhoid fever.

With the above facts established, any opinion addressed to the court to the effect that typhoid fever germs will not and can not pass from Chicago to St. Louis must fall as of slight value indeed, because not being founded upon proper premises and being in conflict with established facts and well known and long established scientific determinations.

We now call attention to the chemical and bacterial data introduced in evidence, showing the physical condition of the Illinois river since the opening of the drainage canal, as compared to its conditon prior thereto:

This evidence shows unquestionably that the water of the Illinois river was more unwholesome and of less value for domestic purposes than prior thereto; that its effect upon the water of the Mississippi river at the Chain of Rocks has been such as to render it also an undesirable and unsafe water.

This testimony of a scientific character, supported by the judgment and opinion of the witnesses, is corroborated by the fact that typhoid fever has increased in St. Louis in conformity with the change of its water supply for the worst.

Defendants' counsel contend that the bacterial and chemical analyses of the water made on the part of their experts show the water of the river to be in a more wholesome condition than prior to the opening of the drainage canal. We call the court's attention to the tables prepared by Prof. Palmer, and found on pages 5568 to 5574 of the Record. It will be remembered that by the addition of 250,000 cubic feet of water to the river its average volume has been more than doubled. The same amount of infectious and polluting material may be depended upon as existing in the river to-day as prior thereto, in addition to whatever infectious and polluting material that may come from Chicago.

In his table of comparative values Prof. Palmer found that at Kampsville, near the mouth of the river, as measured by the total organic nitrogen in the water for the years 1897 to 1902, inclusive, the average for the three years prior to the opening of the canal was 1.0866; and for the three years subsequent to the opening of the canal was .8966, so that the percentage of decrease of organic nitrogen was only 17.48 per cent., while there should have been a decrease of fifty per cent., because of the effect of an increase in the volume of water amounting to fifty per cent. In other words, this table shows that the organic nitrogen has not decreased in the water of the Illinois river at Kampsville, but so far as quantity is concerned has in reality increased. This is convincing proof that instead of having the effect to destroy the substance known as organic nitrogen, the addition of the volume of water from Lake Michigan has preserved and prolonged the existence of such substance in the water.

What is said of organic nitrogen may also be said of dissolved organic nitrogen. While the free ammonia, in spite of the added volume of water, thereby creating a diluting effect amounting to fifty per cent., as shown by the table on p. 5571, has actually increased six per cent. thus evidencing again the strong preservative effect of the diluton of Lake Michigan water upon the infectious and polluting material contained in the river.

The testimony for defendants contains a large number of questions and answers not only inconsistent with the foregoing facts established, but inconsistent with and contrary to the well known and established rules applicable to sanitary science and the longevity of pathogenic bacteria in water.

The opinions of witnesses contrary to physical facts and natural conditons and causes must be disregarded.

State v. Cross, 68 Ia., 180.

People v. Augsley, 97 N. Y., 501.
Underhill on Evidence, Secs. 189-190.

When the opinion of an expert witness is not founded on facts explained in evidence, or applicable to the case at hand, such an opinion is merely speculative, and should not be considered.

Story v. Union Bank, 34 Ala., 637.
Ebo v. State, 34 Ark., 520.

The opinion of experts must always be disregarded when contrary to established laws of nature or contrary to facts admitted as true, or facts established. Such testimony is speculative and never relevant or admissible for any purpose.

Filer v. R. R., 49 N. Y., 42.
Strohan v. R. R., 96 N. Y., 305.
Tozer v. R. R., 105 N. Y., 617.
Turner v. Newburg, 109 N. Y., 301.
Collins v. Janesville, 99 Wis., 464.
Block v. Milwaukee, 89 Wis., 371.
Harpt v. Utah, 120 U. S., 430.
Bram v. U. S., 116 U. S., 569.

Expert opinions of witnesses can not prevail against established evidence.

Highfall v. Mo. Pac. R. R., 93 Mo. App., 219.
Gorman v. R. R., 96 Mo. App., 608.

In speaking of the value of the opinion of witnesses, Wigmore on Evidence, Sec. 659, has this to say:

"The third corollary of the general principle of knowledge is that the witness' knowledge must not ap-

pear to lack adequate data as its basis of inference. For example, when Sherlock Holmes tells his companion that the neatly dressed person who is seen passing on the street is a banker, the father of six children, and a German by birth, the ordinary intelligence will not credit a statement based on such apparently invisible data. Yet if a man passes by in his working clothes, daubed with lime and brickdust, the ordinary intelligence would admit that the observer had the right to assert positively that the man was a brick-layer. Thus it is that the law may reject testimony which appears to be founded on data so scanty that the witness' alleged inference from them may at once be pronounced absurd or extreme. The law denies the witness the right, with such data, to assert that he knows.

"This principle, however sound it is in theory, can seldom have frequent application. When the source of knowledge is so insufficient courts will rarely need to pronounce the formal exclusion of the testimony. Its weakness is self-exhibited. The risk of excluding a useful though small item of testimony is greater than the risk of admitting testimony capable of exaggeration. Cross-examination will usually furnish the exposure."

So here, the opinion of defendants' witnesses, being contrary to well established scientific truths must be disregarded by the court, being founded upon unsatisfactory data so scanty that the witnesses alleged inference should at once be pronounced absurd and extreme.

VII.

THE OPINION OF LAY WITNESSES AS TO THE VALUE OF THE WATER FOR DOMESTIC PURPOSES SHOULD BE EXCLUDED.

In the reply brief of defendants to brief and argument of complainant, p. 10, it is insisted that in an action of this kind where each produce the evidence of a reasonable number of reputable experts, equally schooled in the questions of science at issue, and such evidence shows an irreconcilable conflict, the evidence of numerous non-expert witnesses, who, from personal experience by the actual use of the water and from observations of it, testified that the water of the Illinois river had been improved since the opening of the canal as compared to the previous period, and that such evidence is entitled to more weight than expert evidence.

We do not agree with counsel in the above statement. That the evidence of lay witnesses is competent for the purpose of proving the physical appearance of the water, we do not question. But that it is competent for the purpose of proving that it did not contain deleterious substances, injurious to life and health, we deny.

These lay witnesses were not possessed of sufficient skill to make any determination whatever as to the value of the water for domestic purposes. And in view of the fact that often times water, apparently pure, containing no evidence of contamination visible to the naked eye, has been observed by scientists to be largely made up of deleterious matter, and to contain thousands of pathogenic bacteria, while another quantity of water, unsightly in appearance, bearing all the evidences of a high state of

pollution and infection may, after a careful examination, be found entirely safe for domestic uses.

The evidence of these lay witnesses shows that prior to the opening of the drainage canal, the water of the river was unfit for domestic purposes because of the formation of a green algae scum upon its surface, and because the great body of the river was practically stagnant throughout the entire year. And that the disappearance of the algae formation, and the creation of a continuous current in the river, constitutes the sole basis of the opinion of such witnesses as to the condition of the water.

From the chemical and bacteriological investigations made by the parties in the case it must stand as an admitted fact that there are chemical compounds and bacterial contents in the water of this river since the opening of the drainage canal which lead investigators to believe that it has been subjected to sewage contamination. Also, there can be no question but what more infectious material is now being deposited in the river than prior to the opening of the canal, so that with this state of facts the court can not rely upon the statement of lay witnesses to the effect that the water is now better for drinking purposes than before. In fact, the testmony of these witnesses was largely to the effect that the water of the river, since the opening of the canal, had not been used for drinking purposes; that no municipality since the opening of the canal takes its water supply from the river. Then too, by the increased velocity of the stream and increased volume of water, conditions are produced which have a tendency to greatly prolong the life of disease producing bacteria, as well as to hasten their journey from the source of the infection to the Mississippi river.

Witnesses should not be permitted to speak unless they know, nor should they be permitted to make damaging statements unless they be in a position to speak with certainty as to

the truthfulness thereof, or be sufficently skilled to form some reliable opinion.

Wigmore on Evidence, Sec. 1917, says:

> "The witness must speak as a knower, not merely as a guesser."

Where the witness is conceded to have no greater skill than the jury or court trying the cause he will not be permitted to draw inferences from either questionable or unquestionable data. Such a witness' inferences are inadmissible when the court can be put in a position of equal vantage for drawing an inference. The witness may be permitted to state facts as he saw them, but any statement of conclusion as to the effect to be produced by a given state of facts is not admissible.

Wigmore on Evidence, Sec. 1924.

As to the value of an inexperienced and unskilled lay witness drawing conclusions and undertaking to give expert testimony, we refer the court to the following authorities:

Lean v. State, 16 Ala., 679.
R. R. v. Walker, 93 Ga., 462.
Atlanta v. Bagley, 107 Ga., 157.
Zimm v. Rice, 161 Mass., 571.
Lewis v. Bell, 109 Mich., 189.
Gray v. R. R., 175 N. Y., 440.
Dushan v. Benedict, 120 U. S., 647.

Unless the statement offered as evidence is based upon some fact having probative value it is not admissible.

Wigmore on Evidence, Sec. 10.

Witnesses who are in no sense experts, cannot testify as to matters requiring special knowledge which they do not possess.

Shaw v. Broom Co., 125 Pa. St. 324.
Ry. Co. v. Bruce, 17 S. W. 363.
State v. Punshon, 133 Mo. 55.
Pauf vs. Alteria, 52 N. Y. S. 88.
Elliott on Evidence, Vol. 1, Secs. 673-674.

VIII.

DEFENDANTS HAVE NO POWER OR AUTHORITY UNDER THE LAW TO DISCHARGE THE SEWAGE OF CHICAGO INTO THE CANAL AND THENCE INTO THE MISSISSIPPI RIVER.

Defendants, in their reply to brief and argument of complainant, assert the long established doctrine that municipal corporations have the power to construct and maintain sewage systems for the health and comfort of the inhabitants thereof, and may discharge the same into navigable streams and waters; and inasmuch as such right has been recognized, that the city of Chicago is given authority to discharge its sewage into the canal.

While it is true that municipal authorities have the power to construct and maintain sewage systems for the health and comfort of its inhabitants, yet the right to discharge such sewage into a navigable stream used as the source of water supply by other municipalities, can only be exercised within certain bounds; and then only by virtue of such municipalities occupying the position of upper riparian owners, possessed of a superior heritage.

Although a municipality may, in law, be possessed of a superior heritage always attributed to an upper riparian owner, yet it is not clothed with right or authority to so abuse a stream as to injuriously affect the health, comfort and convenience of those living upon the stream at a point below.

The day is fast approaching when the privilege of discharging sewage into a navigable stream will be entirely withdrawn from municipal authorities. Necessity has been looked upon as the mother of the rule which has permitted such discharges.

The same law of necessity will be asserted and exercised in preventing such use, as population increases and manufacturing enterprises become more numerous.

Aside from the above proposition we are at a loss to see how the authorities cited by defendants can be applicable to the case at bar, for the reason that defendants do not occupy the position of upper riparian owners, and therefore are not entitled to whatever benefits such doctrine may bestow upon those possessed of a privilege by virtue of being riparian owners.

The proposition here involved has been discussed fully at another point in this brief.

IX.

THE ACTS OF CONGRESS OF 1822 AND 1827, AUTHORIZING THE STATE OF ILLINOIS TO CONSTRUCT A CANAL CONNECTING THE WATERS OF LAKE MICHIGAN WITH THE WATERS OF THE ILLINOIS RIVER, DO NOT JUSTIFY DEFENDANTS IN DISCHARGING THE SEWAGE OF THE CITY OF CHICAGO INTO THE ILLINOIS RIVER AND THENCE INTO THE MISSISSIPPI RIVER.

On page 10 of defendants' reply brief and argument the assertion is made that the Acts of Congress of 1822 and 1827 duly authorize the State of Illinois to connect, by means of a canal, the waters of Lake Michigan with the waters of the Illinois river. Therefore the connection of the same and the waters thereof as done, was a lawful act.

The mere connection of the waters of Lake Michigan with those of the Mississippi river are not complained of in this bill. As to whether the act upon the part of the State of Illinois connecting the waters of Lake Michigan with the Illinois river was legal under the Federal statute is a matter of no concern whatever to complainant. The question here involved is the discharge of the sewage from the sanitary district of Chicago into the canal. The acts of Congress referred to in no way undertakes to authorize such conduct, and if the attempt was made in that direction we have no hesitancy in saying that by reason thereof complainant would not be barred of its rights in the premises if actual damage existed.

The case of Wisconsin v. Duluth, 96 U. S., 379, is referred to and quoted at length by defendants. An examination of the above case will disclose that this act grew out of an appropria-

tion made by the Federal Government to improve the harbor at Duluth by the construction of a short canal, three or four hundred feet in length. The question of injury, or the establishment of a nuisance was not involved; in fact, the only question presented of which the court took notice was whether or not Congress had authority to make an appropriation and exercise jurisdiction over the commerce and commercial facilities, harbors and docks of the great lakes of the country. It was found by the courts that Congress had heretofore exercised such right, and that the same was for the benefit of the public. Being an exercise of a governmental power, in the interest of the general public, the court would not undertake to destroy such right or to disturb the improvement that had been made.

The fact that Congress authorizes the construction of a canal drawing the water from Lake Michigan to the Illinois river under no circumstances can be held to imply that persons owning property and residing in the vicinity of such a canal would have the right, without express legislative authority, to discharge sewage and waste into it. In fact the converse is true. By implication no such right exists, nor can any such right be justified, either at law or in equity.

We submit to the court that upon a consideration of law as applicable to the facts at hand complainant is entitled to the relief sought, the damage being substantial, of a permanent character, continuous and at all times imminent.

X.

LONGEVITY OF BACILLUS-TYPHOSUS; OR TYPHOID BACILLI. THEIR PASSAGE FROM CHICAGO TO ST. LOUIS AND THE INJURY SUFFERED BY AND CONTINOUSLY BEING INFLICTED UPON COMPLAINANT SHOWN BY RATIONAL AND CONVICING PROOF.

An attempt is made to discredit the testimony of complainant as to the longevity of typhoid fever germs in running water. Defendants are driven to a reliance upon the correctness of the experiments conducted by Profs. Jordan, Zeit and Russell, in which typhoid germs were kept alive in parchment sacs, suspended in the waters of the Illinois river, for a period of ten days.

It is true that under this testimony a large majority of them had disappeared at the end of the third or fourth days, but in one particular instance they were observed by Prof. Jordan at the end of the tenth day. After making the investigations and obtaining the observations as to their life, an attempt is made not only to discredit the testimony of all the witnesses upon this subject, but also to discredit the accuracy of their own determinations.

In view of the fact that according to the experience of mankind typhoid fever germs have been known to survive for a considerable time and cause typhoid infection in localities far removed, in point of time, from the source of the infection, it is strange indeed that their discovery in these sacs at the end of ten days should be looked upon with suspicion, and characterized as an accident.The fact is, it would be more natural to believe that the discovery of the germs at the end of the tenth

day is conclusive proof of their ability to live through that length of time in the water of the river rather than to assume that they are the result of dried particles of matter hanging to the neck of the sac. Is it not more reasonable to believe that they came from the body of the water deposited in the sac, rather than from any other source?

Defendants undertake to convince the court that this experiment reflects natural conditions, but as stated at a previous place in this brief, their own witnesses were compelled to admit that the experiments did not, in every way, represent natural conditions in the water.

These experiments were made secretly, without knowledge on the part of complainant that it was being done, long after the commencement of the taking of testimony. It was then believed, as now, that typhoid fever germs will live in the waters of a running stream for a period of from fifteen to thirty days. The object of this secrecy has not been disclosed.

Defendants admit that with the parchment sacs suspended in a stationary manner, with the water of the river flowing by, exact natural conditions can not be copied. In other words, the germs of typhoid contained in the water are not subject to the benefit of whatever degree of bacterial destruction that may be going on in the water. In fact, numerous objections suggest themselves, applicable alike to conditions in a laboratory.

After these experiments were made and introduced in evidence no time remained before the testimony was closed for complainant to test their accuracy. It is sufficient here to say that the result of these experiments so conducted by Profs. Zeit, Jordan and Russell has not met with the approval of practical scientists who are in a position to know and observe.

We quote below an article from the "Engineering Record," giving the result of determinations made on the presence of b-coli

made at Columbus, O., shortly after the testimony in this cause had been closed. The experiment in question shows conclusively that bacilli coli instead of remaining in the parchment sacs were able to pass through the walls of the sac, and disappear into the water in which the sacs had been suspended.

Coli bacilli resemble largely bacilli typhosus, both as to size, shape and longevity. If, then, it be found that bacilli coli might walk through the walls of a sac it must be admitted that typhiod bacilli will do likewise.

The articles above referred to are found on pp. 337 and 344 of the Engineering Record of date September 23, 1905. We here quote them as constituting a convincing argument against the correctness and accuracy of the experiments conducted with the parchment sacs by Profs. Jordan, Zeit and Russell:

> "Sanitary engineers always welcome new data to throw further light on the life of typhoid bacilli in sewage and water. The importance of this question in many problems of water supply, sewage disposal and self-purification of streams easily accounts for this interest. For some fifteen years the general views of prominent workers in this field remained about the same and were based upon the results of numerous experiments made in the laboratory upon the life of typhoid fever germs in various waters. These experiments, made both in Europe and in this country, notably at the Lawrence Experiment Station, were quite harmonious on the whole. They indicated that typhoid fever germs do not apparently, under any conditions in practice, multiply in water, but, on the contrary, that they die out gradually, with a small but varying percentage of these bacilli living for periods of from one to three weeks or more, depending partly upon the shortcom-

ings of laboratory methods and partly on local conditions, the full significance of which is not understood.

"Independently of laboratory experiments, engineers for some years have appreciated that typhoid fever germs in fecal matter may live under some circumstances for several months or longer, especially during cold weather. This has been demonstrated conclusively by some of the unfortunate typhoid fever epidemics which have occurred in various cities, among which may be mentioned the one at York, Pa., in 1897, and the one at New Haven, Conn., in 1901. Under some conditions, especially in the soil, it is manifest that some typhoid fever germs can and do live for many months. Indeed, it is obvious that in some way these bacilli perpetuate themselves for quite long periods, sufficient to keep the disease from becoming exterminated in rural districts.

"Last year the results of extensive experiments upon the life of typhoid fever germs in various waters associated with the Chicago Drainage Canal project were published by Drs. Jordan, Russell and Zeit. The results of these experiments were reviewed in connection with other similar data by Mr. George C. Whipple, in The Engineering Record of Dec. 24, 1904. In brief, the experiments of these three gentlemen embodied technique by which improvements appeared to have been made through the use of collodion or parchment sacs for containers in place of bottles, such as were formerly used for this purpose. It was claimed by these and other investigators that experiments made with samples of water inoculated with typhoid fever

bacilli and allowed to stand in glass bottles do not correspond with conditions in practice in that the typhoid bacilli do not have access to fresh water or fresh bacteria; but that they remain in contact with bacteria and their products within the bottle, and in this way the antagonism of ordinary water bacteria toward typhoid bacilli is materially reduced. Consequently it was claimed that the longevity of the typhoid bacilli, as tested in glass bottles, was greater than under actual natural conditions.

"These experiments led the authors to conclude that in the local waters the vast majority of typhoid fever germs perished in three to four days. Although they disclaim the applicability of these data to all other conditions in natural bodies of water, the obvious influence of such data assigning an unusually short life to these germs is to make some people less conservative than formerly regarding the vital question of typhoid fever infection through drinking water. Indeed, several instances appear to have recently occurred where sanitarians, as a result of these investigations, have tacitly consented, or at least have not objected, to procedures which ordinarily would be vigorously protested against by those experienced in matters of public water supply.

"Among the several incidental features of interest and importance which developed at the symposium on copper sulphate treatment at the New England water works convention last week were the remarks of Mr. George A. Johnson in reference to certain investigations forming a portion of the various tests made under his immediate charge during the past year at the

Sewage Testing Station at Columbus. His remarks in connection with the permeability of parchment sacs appear on page 344 of this issue and bring clearly to the front the question of the reliabiilty of experiments made with such sacs in studying the life of typhoid fever germs in water.

"In brief, he showed that unpunctured sacs which maintained their initial integrity throughout the tests, so far as dialyzing properties are concerned, were unable to prevent motile bacteria from passing through the walls of the sacs. Details of the technique employed by him and his associates were concisely outlined and apparently offer a plausible explanation, in part at least, of why experiments on the life of typhoid bacteria conducted in this way point to the conclusion so different from those generally held previously. The manner in which motile bacteria are able to pass through such sac walls is not perfectly clear, but it is not necessary to explain in minute detail all of the various scientific factors involved in such passage. There remains the fact that apparently with the most careful technique typhoid fever germs are able to pass from collodion sacs, thus throwing serious doubt upon the alleged short life of the typhoid fever germs supposed to have remained and died within the sac.

"For some time it has been known that unpunctured sacs are not necessarily germ tight. This was supposed to be due initially to defective sacs. The Columbus observations indicate that this diffiulty is not as easily guarded against and prevented uniformly as was supposed, and that sound data from the

use of sacs involves the necessity of establishing the integrity of each sac against the passage of motile bacteria not only at the beginning but at the end of the test. Another point of significance was brought out both by Mr. D. D. Jackson of Brooklyn and Mr. Johnson, namely, that ordinary laboratory cultures of typhoid fever germs become debilitated, and, compared with virulent germs just removed from the animal body, are much more readily killed by natural causes as well as by the copper sulphate treatment.

"Further investigations along this important line will no doubt bring added information, but in the meantime it seems prudent for sanitary engineers not to readjust too quickly their views held for a dozen years or more on this question, and not to allow needless risks to be taken on the basis of tests which do not seem to have reached a solid foundation."

EXPERIMENTS WITH TYPHOID GERMS AT THE COLUMBUS TESTING STATION.

Among the investigations recently made at the Sewage Testing Station at Columbus were experiments to determine the reliability of the methods followed by Messrs. Frost and Jordan, Russell and Zeit in certain determinations of the life of typhoid fever germs. In these determinations parchment and collodion sacs were used to contain the germs, instead of the usual bottles, and the experiments at Columbus were made to ascertain the propriety of this change in method. At the recent meeting of the New England Water

Works Association, Mr. George A. Johnson, chemist of the Station, made the following important statements concerning this subject:

"These somewhat conflicting data (the conclusions of Frost and Jordan, Russell and Zeit, respectively), suggest the possibility that the collodion sacs offered less opportunity for the exit of the highly motile typhoid bacilli through the walls of the sacs than did the sacs of parchment. If this was not so the thought presents itself that possibly after several days of service the initial integrity of the parchment sacs was impaired to an extent sufficient to permit of the escape therefrom of the typhoid bacilli. To place the results of studies of this character upon a perfectly sound basis, positive data and statements are required to show whether the initial bacterial integrity of the sacs containing the typhoid bacilli continued unimpaired throughout the experiment.

"Such definite information as referred to is called for, in the opinion of the writer, for the reason that studies in this line at the Columbus Sewage Testing Station have shown that in some instances parchment sacs, possessing initially and retaining throughout the experiments perfect integrity so far as their dialyzing properties were concerned, permitted the escape therefrom of B. coli when immersed in distilled water; and, further, similar sacs containing sterilized water, when submerged in flowing streams of sewage and polluted water, permitted the entrance in a comparatively short time of large numbers of bacteria, including B. coli. Typhoid bacilli were not studied in this connection, but the conclusion may be justly drawn, in view of

the highly motile character of the typhoid bacillus, that if other less motile forms could pass through the walls of the parchment sacs under such conditions, there is no room for reasonable doubt regarding the ability of typhoid bacilli to act in a similar manner. The results of the Columbus studies referred to are presented in the accompanying tables:

RESULTS ILLUSTRATIVE OF ESCAPE OF B. COLI THROUGH WALLS OF PARCHMENT SACS IMMERSED IN STERLIZED WATER.

Time sacs were suspended in sterilized water.	B. coli per C. C. in water surrounding sacs.		
	Sac A	Sac B	Sac C
0 hours	0	0	0
24 hours	Over 1,000	Over 1,000	Over 1,000

RESULTS ILLUSTRATIVE OF PASSAGE OF B. COLI THROUGH WALLS OF PARCHMENT SACS FROM OUTSIDE.

Sacs suspended in flowing stream of	B. Coli per C. C. in water contained in sacs. Number of hours sacs were exposed in current.		
	0	48	72
Crude sewage	0	320	2,000
Septic sewage	0	320	2,000
Septic sewage	0	120	1,100
Eff. of a sewage filter	0	400	2,000
Polluted water	0	0	40

"In the first series of the experiments the parchment sacs were filled with a 5 per cent solution of starch, both ends tightly tied, and the sacs then immersed in half-gallon bottles containing tap water. These bottles were plugged with cotton, one end of the sacs protruding. These bottles were then autoclaved, and after being allowed to cool, the protruding ends of the sacs were opened and one cubic centimeter of a broth culture of B. coli communis introduced into each of the sacs. The water outside the sacs was then tested for starch and for B. coli. The results were negative

in all cases. The bottles were then permitted to stand for 24 hours, when the water outside the sacs was again tested for starch and B. coli. The starch test gave a negative result in all cases. B. coli were found in large numbers in all cases, as shown in the table.

"In the second series of experiments the sacs were filled with tap water, sterilized, and tested for sterility, which was found to be perfect in all cases. The sacs were then suspended in flowing streams of sewage and polluted water, the contents being tested at intervals for bacteria. Inside 48 hours bacteria appeared in the sacs, as shown in the tables. The dialyzing properties of all the sacs were carefully tested at the beginning and at the end of this, as well as in the case of the other series of experiments, and were found to be unimpaired in all cases."

In referring to the parchment sac experiments conducted by Profs. Zeit, Jordan and Russell, Dr. Herbert E. Smith, at pp. 7709 of Record, stated:

"In my opinion these experiments do not exemplify the true conditions—the conditions which exist in the water of the drainage canal in relation to the life of typhoid bacilli discharged into that as a part of the sewage.

"The opinion is based on several points. First, the introduction of typhoid bacilli in an artificial culture in such a quantity of sewage enclosed in a parchment sac as to protect it. This does not assimilate the conditions which would exist in typhoid bacilli discharged into sewage, and coming from a patient suffering from typhoid fever, in which case the organisms may readily

be, and frequently are, enclosed in solid masses. Further, the condition of the bacilli in this sac is quite different from that which they would be under if they were free in the stream, where they would be free to settle and become deposited in the sediment so as to be protected from the influence of the sewage upon them.

"In my opinion the condition of the water would frequently change at any one spot, owing to the changeable condition of the discharge which I find coming from the sewers at Chicago. The difference in the flow between day and night would make a difference in the composition of the sewage water at any one place, and, further, the flow at night is very different in composition from the flow during the day.

"If the destructive action which was found in this case was due in any way to the concentration of the sewage, the further the bacilli moved down the stream the less they would be subjected to this, because of the increased dilution in the lower stretches of the river.

"Q. Doctor, state whether or not, in your opinion, you know of any bacteriologists, epidemiologists or sanitarians who have limited the longevity of the life of the typhoid germ in sewage, or sewage polluted water, to less than six days.

"A. I know of no previous experiments which were of such character as to warrant the experimentors in making such an assertion. I do not recall such limitations placed upon them by anyone.

"As far as I know, this period of time is shorter than that given by other authorities. More experiments of this sort have demonstrated that sewage in

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"As far as I know, this period of time is shorter than that given by other authorities. More experiments of this sort have demonstrated that sewage in

concentrated form is detrimental to the life of typhoid bacteria, but the length of time which bacteria have lived in sewage, according to the different experiments, have been so various that I do not recall a limitation expressed by any standard authority upon this subject. One set of experiments, however, that I have in mind, are those of Dr. Horricks, who showed that typhoid bacilli survived in unsterilized sewage for a period of fourteen days, and there have been other experiments made by different experimentors on this point.

"As I state, I do not know of anyone who has felt justified, as the result of these experiments, of limiting the period which typhoid bacilli might survive in sewage when they were introduced in what we might speak of as a natural media, and under natural conditions."

In speaking from the tables or analyses introduced in evidence in the cause, based upon the experiments made by Drs. Zeit, Jordan and Russell, Dr. Smith made the following statement:

"Taking into consideration the various data to which you have called my attention, I would state that I have been able to find no evidence which, to my mind, is conclusive that the agencies at work in the stream are adequate to destroy the typhoid bacilli which undoubtedly are introduced into the sewage of Chicago, and through it into the Illinois river, and therefore I believe that dangerous and infected pollution might reach the intake of the St. Louis waterworks; and I would state that, considering all the data which I have been able to consider as bearing upon this problem, I

believe that typhoid bacilli, from the sewage of Chicago, have reached the intake of the St. Louis waterworks."

"In my opinion the data available, especially with reference to the typhoid conditions upon the watershed of the Mississippi and Missouri rivers, above the intake of the St. Louis waterworks, and the data concerning the occurrence of typhoid fever in the Chicago Sanitary District are sufficient to show that the increase of typhoid fever has been due, in a considerable part at least, to the infection of the Chicago sewage." (Record, pp. 7714 and 7716.)

In reference to the parchment sac experiments, Mr. Lockridge, at pp. 7948 and 7949, testified as follows:

"Q. State whether or not, in your opinion, the results of these experiments represent or simulate natural conditions?

"A. I do not think they do.

"Q. Why?

"A. In the first place any sac lodged at one place will receive the influence, if the osmotic conditions are as perfect as is supposed, of sewage which is fresher continually than would be in contact with similar germs passing down the stream. The actual influence, if there is any, of the sac itself, is not known. The results vary to some extent from earlier results obtained by various bacteriologists on this same point. There were but three of the series of Professor Jordan's experiments in the drainage canal at either Robey street or at Lockport, in which the typhoid or-

ganisms were found at all *after* 10 minutes had elapsed, with the exception of one case where it was found ten minutes after inoculation. Of these three cases one is recorded instance of its occurrence on the 10th day. This has been attributed, by Professor Jordan, to the fact that bacteria, and especially the typhoid bacteria, may be dried against the neck or some part of the sac, and thus be subjected to conditions of greater longevity. This is a possible explanation for this, but there seemed to me to be other explanations. It is a fact, recognized in general, I believe, by bacteriologists that of several forms of micro-organisms in the water that one of these forms will apparently mask the others, as in the case of experiments with colon and streptococci.

"In the earlier periods the colon masks the streptococci, so that but few or none are seen. While later the streptococci develop much more abundantly, and to an extent over-growing the coli. Later, however, the coli may again appear. Considering this principle, it may have been impossible on any of the earlier determinations to have detected the typhoid, although there is no conclusive proof that they were of necessity absent up to the time of this appearance on the tenth day, and the three typhoid colonies found may be ascribed to the fact that their presence was masked before that date. In regard to the other determinations of Prof. Jordan, showing that the typhoid were certainly alive in two cases after the second day, indicates that this germ will live at least this long, but I do not believe that it necessarily shows that they do not live longer."

"Q. State whether or not in the parchment sacs, in which the fecal matter and the urine of typhoid patients was deposited by Professor Jordan, that the typhoid germs might not have been encased in particles of fecal matter and thus preserved?

"A. It seems to me quite probable that they may have been thus encased, and in this way have lived for a considerable period of time.

"Q. State whether or not these experiments maintained natural conditions in the waters of the canal and the Illinois river at all times of the year, and all seasons of the year?

"A. I do not believe that they do. The experiments were attempted at one season of the year, I believe, the fall, and for this reason I do not believe that they simulate all conditions of flow and the conditions prevalent in all seasons of the year."

Prof. Sedgwick is just as emphatic as either Dr. Smith or Mr. Lockridge in his criticism of the accuracy of the foregoing experiments in disclosing the true longevity of typhoid germs in the interchangeable condition of the water in a flowing stream. At pages 7960, '61, '62 and '63, Prof. Sedgwick testified as follows:

"Q. Prof. Sedgwick, have you examined the testimony of Prof. Jordan, Dr. Zeit and Prof. Russell concerning their experiments upon the longevity of the typhoid germs in parchment and celloidin sacs and agar blocks suspended in Lake Michigan, the Chicago river, the Drainage Canal and the Illinois river, and all other similar experiments made by these gentlemen and introduced in evidence?

"A. I have.

"Q. State whether or not you are able, from the determinations made by them in the above connection, to formulate an opinion as to the longevity of typhoid organisms contained in these waters?

"A. No, I should not be able either to form or to formulate a comprehensive opinion from these experiments alone. It is clear, of course, as shown in these experiments, the germs survive for certain lengths of time, but I should be unable to conclude from the experiments that under different conditions typhoid fever germs might not survive for longer times. The experiments appear to me to have been very ingenious and interesting, but not by any means conclusive upon the whole subject of the longevity of typhoid fever germs in moving bodies of sewage or water.

"Q. State whether or not, in your opinion, these experiments just referred to simulate natural conditions in the water?

"A. Undoubtedly they were devised as far as possible to do this, but in a great deal of experimental work the result of the experimentor falls short of his endeavors. I do not see how it is possible, in the present state of bacteriology, to devise any series of experiments which shall accurately and completely imitate the infinitely various conditions of running streams, and particularly streams such as the Chicago river, the Chicago Drainage Canal and the Illinois rivver, subject as these are, to an endless variety of alterations, in their physical, chemical and bacteriological conditions.

"For example, these experiments were carried on in cold weather, I believe, but even if they had been carried on for an entire year, under all actual variations and conditions, they would still, in my judgment, have been incomplete for the reason that in other years, under other conditions, organisms as sensitive as typhoid fever microbes are, might have encountered environments which would have materially altered the results. Besides it seems to me that the conclusion arrived at by these able investigators indicate a shortness of life of the typhoid fever germs which is not in harmony with the longevity naturally deducible from the experience of mankind with epidemics due to typhoid infected waters, and while evidence of this kind is hard to reduce to a strictly scientific basis, it has, I believe, nevertheless great value, for the reason that it is the outcome of the experience of the race.

"Furthermore, the results of these experiments, broadly speaking, indicate a considerably shorter period of life for the typhoid fever germs in sewage and water than has been found by the majority of previous investigators. My own opinion is that a greater number of experiments, conducted for a longer time, and under different conditions, would not fail to show that typhoid fever germs may, and do, live in sewage and running streams a very much longer time than was found in these particular experiments.

"Q. In what particular way did these experiments fail to represent true natural conditions?

"A. I should not say that these experiments failed to represent natural conditions any further than many experiments must necessarily fail to imitate natural

conditions. I mean by that, that these experiments were undoubtedly well planned and well conducted, but it is easy to suggest a great number of points in which they do, nevertheless, fail, the principal failure being to duplicate all the various conditions of the running stream. Some other matters have already been mentioned by witnesses for complainant in rebuttal, such, for example, as the fact that the germs in the several experiments were anchored, so to speak, at fixed points, instead of being allowed to float down the stream with a particular body of water. Anyone can readily see that this is an unnatural condition, especially in the case of the drainage canal, and the Chicago and Illinois rivers, for the reason that the chemical composition of these bodies of sewage and water is subject to frequent changes. If, for example, the waste from a large industrial establishment should be turned into the Chicago river at any particular moment, the water which received it would vary materially in chemical composition from the water just preceding and just following it. For this reason sacs or blocks at anchor are probably exposed to a greater variety of changes than they would be exposed to if they were to float down the stream with one particular body of water.

"The sewage discharged from a city at night is a very different body, chemically, from that discharged by day. The sewage discharged during a heavy storm is very different from that discharged in dry weather. Again the seasonal conditions must be taken into account, and in the case of the Illinois river, physical conditions, such as floods in the tributaries, or the overflow of lakes upon these tributaries, bringing in new

materials and a strange bacterial flora. These and many other things, which I need not and could not mention, undoubtedly play a highly important part. The trouble is, that in trying to fix the longevity of typhoid fever or any other microbes, we are dealing with extremely sensitive and almost infinitesimal organisms, which we have only within the last few years learned to recognize at all, and have not yet by any means learned to know thoroughly. I believe, therefore, that while the experiments of the experts for the defense are interesting, ingenious and important, in the science of bacteriology, they should not be allowed to have too much weight in determining the issues in this case.

"Q. Assuming, Professor, that the longevity of a typhoid fever germ in an open sewer, such as the Drainage Canal, as characterized by different witnesses, and as limited by the experiments of Dr. Zeit, Jordan and Russell, to from two to four days, in what respect is the credibility of these experiments reflected upon by the ordinary, usual and general practice of sanitarians in the construction and recommendations for the construction of plants for the treatment of water for domestic purposes, which has been subjected to sewage pollution?

"A. As I understand the question, it is my opinion that their results are so far out of harmony with the results of previous investigators and so contrary to the prevailing opinion upon this subject which forms the basis of the practice of sanitarians and engineers in forming their opinions concerning the availability of polluted streams for drinking and other domestic purposes, as to throw grave doubt upon the results, and

therefore upon the conclusions to which these naturally lead."

It is apparent from the foregoing explanations that the experiments in various material ways failed to respond to the natural conditions of a running stream. Mr. Lockridge refers to the osmotic conditions, which are intended by these experiments to be fully preserved, as absolutely essential. Profs. Zeit, Jordan and Russell speak of the impervious condition of the sacs, which is intended so as to prevent the germs contained in the sac from passing out, and also to keep out the germs known to exist in the running water.

It must be observed, therefore, that the sacs must be perfectly impervious so far as the germs are concerned, and perfectly osmotic so as to obtain a complete and perfect mixing of the liquid contents of the sac with liquid from the running stream. To approach perfection in either instance is practically impossible. A sac may be said to be impervious at the time of its being deposited in the water, but a few short hours may altogether change its condition. So it may also be said to be of such character as to thoroughly permit proper osmotic conditions, and at the same time guarantee the degree of imperviousness required, but how long this condition does exist is unknown. It is, therefore, natural to suppose that, as it remains suspended in the water, these very material conditions are constantly changing, and on account of the very minuteness of the bacteria the impervious condition may become crippled to such an extent as will permit the passage of the germs from the sacs into the water, and likewise from the running water into the sacs. The osmotic condition may also become so changed as to prevent the passage of liquid substances and toxic products from the running stream into and through the sacs, likewise preventing such passage from the sacs into the stream.

Properly considered, the test is entirely too indefinite and uncertain to be of consequential value. In fact this test is more delicate and intricate, so far as guarding against possible material changes are concerned, than experiments conducted in the laboratory. The objections here set forth are confirmed by the arguments presented in the "Engineering Record," and the result of the experiments therein referred to.

This evidence, so firmly relied upon by defendants, is not only subject to the material objections above presented, but from a practical standpoint is in direct conflict with the evidence upon the longevity of typhoid fever germs, introduced on behalf of complainant, and also with the admitted belief and experience of defendants' expert witnesses. The result of these experiments is entirely different from any that has been heretofore obtained, and therefore their accuracy must depend solely upon the fact that natural conditions were imitated, and that the typhoid organisms used in the experiment were of equal vitality, and contained the average number of specially resistant cells as are found in ordinary sewage coming from a community infected with typhoid fever. They unquestionably conflict with the testimony of the following witnesses, many of whom were produced by defendants:

Ravold, Complainant's witness, Record, pp. 468, 476, 478, 479, 480, 790, 792.

Whipple, Complainant's witness, Record, pp. 2081 and 82.

Sedgwick, Complainant's witness, Record, pp. 2197-8-9, 2207, 2238, 2310-11-12-13-14 and 2765.

Fuller, Complainant's witness, Record, pp. 2617-18, 2626-27, 2628-29, 2664-65.

Herring, Defendants' witness, Record, pp. 7026-7-9.

Jordan, Defendants' witness, Record, pp. 6855-56-57-58, 6176, 6180.

Russell, Defendants' witness, Record, pp. 651-2-13, 6600, 6602.

Mason, Defendants' witness, Record, pp. 6960-61-62-63-64.

Barker, Defendants' witness, Record, pp. 7131, 7134-35, 7167.

Hill, Defendants' witness, Record, pp. 7509, 7516-17-18.

It will be well to note that the opinions of defendants' witnesses with reference to the ability of pathogenic bacteria to pass from Chicago to St. Louis within the lifetime of the germ, are based upon the result of the determinations made according to the aforesaid parchment sac experiments. In nearly every instance special attention was called by the witnesses to the fact that the result of these experiments had been adopted by them in determining the longevity of the germ, and its ability to survive the trip from Chicago to St. Louis. In this connection Prof. Jordan, at page 6180, said:

> "I base my opinion chiefly upon the elaborate experiments that I have recently carried out upon the life of typhoid germs under natural conditions in the water of the drainage canal at Robey street and at Lockport.
>
> "Q. Was this experiment conducted by yourself alone?
>
> "A. No, sir; by arrangement with the Sanitary District of Chicago the experiment was conducted under the supervision of Prof. Russell of the University of Wisconsin and Zeit of the Northwestern Medical

School and myself. It was a cooperative experiment, special features of the work being assigned to each investigator."

We again refer, in this connection, to the fact that Prof. Jordan discovered three colonies of pure typhoid in the parchment sac experiment in the waters of the canal after they had been suspended in the water for a period of ten days. In view of what has just been said with reference to the longevity of the germ and the general belief of scientists upon the subject, and the result of years of study, we ask the court: Is it not more natural to believe that the germs found were such as had remained in the water contained in the sac, or in some particle of solid material while contained in the water, rather than to have been the result of a particle of dried substance hanging to the neck of the sac?

We also ask the court, is it not dangerous to undertake to assert that simply because these experimentors were unable to keep the germs alive for a longer time than as testified to by them, or were unable to discover them after a longer time, a fixed formula can be applied to the waters of the Illinois river by which it can be said that after four or five days of travel the germs will all have perished or disappeared?

Is it not better to adopt the well known practical belief that has been followed by bacteriologists and sanitarians, and which absolutely conforms to the experience of mankind in dealing with typhoid fever?

Is it not more rational to hold that typhoid fever germs will live for a period ranging from ten to thirty days in the waters of a running stream, based upon the history of the disease and its causation, as observed by the profession of sanitary scientists?

Is it not more rational and material to determine the probable cause of the increase of typhoid fever in St. Louis than to undertake to say that a certain act or condition charged as the cause will not produce the effect complained of when it is shown in evidence that such increase in typhoid commenced immediately after the appearance of the cause under consideration, with no other known or reasonable cause existing?

In this connection we call the court's attention to a hypothetical question, based upon the facts introduced in evidence, and propounded to Prof. Sedgwick. From these facts, together with the favorable result obtained from an examination for all local causes of infection complainants' witnesses expressed their opinions as to the cause of the increase of typhoid in St. Louis. The question above referred to, and the answer to it, may be found on pages 2239 to 2250 of the printed record, as follows:

> "Q. Assuming that the following cities are situated on the water-shed of the Missouri river; that the sewage of said cities is discharged directly or indirectly into the Missouri river, as hereafter indicated, and that the respective population, according to the census of 1900, and the distance from St. Louis, as well as the number of deaths from typhoid fever in each city for the years given, is as follows:
>
> St. Charles, Missouri; population 7,982; 47 miles from St. Louis.
>
> Deaths from typhoid fever:
>
> 1899, 22.
> 1900, 5.
> 1901, 6.
> 1902, 14.
>
> Kansas City, Missouri; population, 173,752; 403 miles from St. Louis.

Typhoid fever deaths:

1893, 59.
1894, 37.
1895, 34.
1896, 29.
1897, 38.
1898, 49.
1899, 52.
1900, 49.
1901, 58.
1902, 58.

St. Joseph, Missouri; population, 102,000; 501 miles from St. Louis.

Typhoid deaths:

1892, 29.
1893, 20.
1894, 22.
1895, 31.
1896, 19.
1897, 13.
1898, [illegible]
1899, [illegible]
1900, 20.
1901, 12.
1902, 13.

Omaha, Nebraska; population, 102,552; 676 miles from St. Louis.

Typhoid deaths:

1893, 22.
1894, 40.
1895, 29.
1896, 18.

1897, 22.
1898, 32.
1899, 26.
1900, 24.
1901, 23.
1902, 22.

Council Bluffs, Iowa; population, 25,802; 676 miles from St. Louis.

Typhoid deaths:

1893, 5.
1894, 7.
1895, 6.
1896, 8.
1897, 8.
1898, 6.
1899, 11.
1900, 6.
1901, 6.
1902, 8.

Lincoln, Nebraska; population, 40,169; 745 miles from St. Louis. (All of these distances are by water.)

Typhoid deaths:

1893, 33.
1894, 21.
1895, 23.
1896, 15.
1897, 14.
1898, 12.
1899, 13.
1900, 4.
1901, 13.
1902, 10.

That the sewers of all the cities just named discharge their sewage directly into the Missouri river, except Lincoln, Nebraska, which discharges into the Platte river, and thence into the Missouri river.

Also, assuming that the following cities are situated on the water-shed of the Mississippi river; that the sewage of said cities is discharged directly or indirectly into the Mississippi river above Grafton, Illinois; that their respective population, according to the census of 1900, their distances from St. Louis, by water, and the number of deaths in each city from typhoid fever for the years named, are as follows

Quincy, Illinois; population, 36,000; 148 miles from St. Louis.

Typhoid deaths:

1893, 21.
1894, 28.
1895, 25.
1896, 13.
1897, 13.
1898, 7.
1899, 6.
1900, 10.
1901, 14.
1902, 17.

Keokuk, Iowa; population, 14,041; 185 miles from St Louis.

Typhoid deaths:

1893, 8.
1894, 13.
1895, 2.
1896, 3.

1897, 7.
1898, 9.
1899, 9.
1900, 10.
1901, 4.
1902, 8.

Burlington, Iowa; population, 23,201; 225 miles from St. Louis.

Typhoid deaths:

1893, 8.
1894, 10.
1895, 8.
1896, 13.
1897, 3.
1898, 4.
1899, 8.
1900, 13.
1901, 12.
1902, 11.

Rock Island, Illinois; population, 35,300; 310 miles from St. Louis.

Typhoid deaths:

1893, 15.
1894, 13.
1895, 3.
1896, 13.
1897, no record.
1898, no record.
1899, 10.
1900, 14.
1901, 28.
1902, 5.

Davenport, Iowa; population, 35,254; 310 miles from St. Louis.

Typhoid deaths:

1893, 5.
1894, 6.
1895, 4.
1896, 3.
1897, 5.
1898, 2.
1899, 12.
1900, 14.
1901, 11.
1902, 11.

Moline, Illinois; population, 7,987; 313 miles from St. Louis.

Typhoid deaths:

1893, 7.
1894, 9.
1895, 8.
1896, 11.
1897, 3.
1898, 5.
1899, 20.
1900, 22.
1901, 16.
1902, 7.

Des Moines, Iowa; population, 62,139; 387 miles from St. Louis.

Typhoid deaths;

1893, 22.
1894, 29.
1895, 30.

1896, 14.
1897, 20.
1898, 17.
1899, 13.
1900, 7.
1901, 22.
1902, 21.

Minneapolis, Minnesota; population, 102,718; 707 miles from St. Louis.

Typhoid deaths:

1893, 134.
1894, 107.
1895, 88.
1896, 60.
1897, 148.
1898, 86.
1899, 71.
1900, 13.
1901, 121.
1902, 66.

St. Paul, Minnesota; population, 163,055; 694 miles from St. Louis.

Typhoid deaths:

1893, 51.
1894, 32.
1895, 38.
1896, 37.
1897, 22.
1898, 43.
1899, 30.
1900, 30.
1901, 24.
1902, 18.

Assuming that all the sewage from said cities entered directly into the Mississippi river except from Des Moines, which is discharged first into the Des Moines river, and from thence into the Mississippi river, about two miles below Keokuk, Iowa.

Assuming, further, that the following cities are situated on the water-shed of the Illinois river, that their sewage flows directly or indirectly into the Illinois river; that they are situated above St. Louis and their population, according to the census of 1900, and their typhoid fever deaths for the years named are as follows:

Peoria, Illinois; population, 56,000; 198 miles above St. Louis.

Typhoid deaths:

1896, 13.
1897, 18.
1898, 18.
1899, 12.
1900, 23.
1901, 15.
1902, 18.

Springfield, Illinois; population, 34,159; 191 miles from St. Louis.

Typhoid deaths:

1900, 20.
1901, 10.
1902, 8.

Bloomington, Illinois; population, 23,286; 191 miles from St. Louis.

Typhoid deaths:

1893, 12.
1894, 14.
1895, 15.
1896, 9.
1897, 10.
1898, 16.
1899, 9.
1900, 15.
1901, 9.
1902, 15.

Ottawa, Illinois; population, 10,588; 282 miles from St. Louis.

Typhoid deaths:

1893, 2.
1894, 5.
1895, 2.
1896, 2.
1897, 4.
1898, 4.
1899, 3.
1900, 3.
1901, 5.
1902, 2.

Decatur, Illinois; population, 20,754; 256 miles from St. Louis.

Typhoid deaths:

1893, 5.
1894, 7.
1895, 2.
1896, no record.
1897, 2.

1898, 5.
1899, 7.
1900, 11.
1901, 5.
1902, 4.

Joliet, Illinois; population, 29,000; 322 miles from St. Louis.

Typhoid deaths:

1893, 12.
1894, 14.
1895, no record.
1896, 12.
1897, 12.
1898, 15.
1899, 13.
1900, 13.
1901, 13.
1902, 21.

Pekin, Illinois; population, 6,420; 188 miles from St. Louis.

Typhoid deaths:

1900, 2.
1901, 1.
1902, 2.

Elgin, Illinois; population, 22,433; 348 miles from St. Louis.

Typhoid deaths:

1893, 5.
1894, 3.
1895, 5.
1896, 14.
1897, no record.

1898, 4.
1899, 5.
1900, 15.
1901, 15.
1902, 8.

Aurora, Illinois; population, 24,147; 328 miles from St. Louis.

Typhoid deaths:

1893, 6.
1894, 12.
1895, 19.
1896, 10.
1897, 5.
1898, 10.
1899, 4.
1900, 17.
1901, 11.
1902, 2.

Havana, Illinois; population and distance not given.

Typhoid deaths:

1893, 3.
1894, 7.
1895, 2.
1896, 5.
1897, 1898 and 1899 not given; no record.
1900, not given.
1901, 1.
1902, 2.

Assuming that the total number of deaths from typhoid fever occurring in the cities of St. Charles, Missouri; Kansas City, Missouri; St. Joseph, Missouri;

Omaha and Lincoln, Nebraska; Council Bluffs, Iowa, on the Missouri water-shed; Quincy, Illinois; Keokuk, Burlington and Davenport, Iowa; Rock Island and Moline, Illinois; Des Moines, Iowa; Minneapolis and St. Paul, Minnesota, on the Mississippi river water-shed, above Grafton, and Peoria, Ottawa, Decatur, Joliet, Elgin and Aurora, Illinois, on the Illinois river water-shed, was for the years 1897 to 1902, inclusive, as follows:

1897, total deaths, 369.
1898, total deaths, 357.
1899, total deaths, 385.
1900, total deaths, 338.
1901, total deaths, 442.
1902, total deaths, 365.

Assuming that the total number of deaths from typhoid fever on said water-sheds in all other towns and cities of 4,000 population and over have not increased for said years in any greater or different proportion than in the cities above mentioned in detail.

Assuming that the three rivers mentioned run through alluvial soil principally and the Illinois river enters the Mississippi at Grafton, 29 miles above the Chain of Rocks Intake Tower of the St. Louis Water works; that the Missouri river enters the Mississippi river twenty-three miles below Grafton, and six miles above the Intake Tower of the St. Louis Water Works located on the Missouri side of and in the channel of the Mississippi river, about fifteen hundred feet from the Missouri shore.

Assuming that the city of St. Louis obtains its water from the Mississippi at the Intake Tower of the St. Louis Water Works, by which it supplies its citizens, about 600,000 in number, with water for drinking and domestic purposes, and that no substantial change in the method of taking said water or treatment thereof has occurred since January 17th, 1900.

Assuming that the sewage of 1,500,000 inhabitants of Chicago has, since January 17th, 1900, been discharged into the Chicago Drainage Canal at Lockport, 291 miles above Grafton, and that the sewage polluted water from said city and canal has continually, since said day, proceeded into the Desplaines river at Lockport, and that the Desplaines enters into and is tributary to the Illinois river, forming a continuous watercourse from Chicago to the Missouri shore of the Mississippi river and to St. Louis.

Assuming that in the years 1895 to 1902, inclusive, the number of deaths in Chicago from typhoid fever was as follows:

1895, 518.
1896, 751.
1897, 437.
1898, 636.
1899, 442.
1900, 336.
1901, 509.
1902, 801.

And assuming that in St. Louis, for the years 1900, 1901 and 1902, and to this day the percentage of annual typhoid fever mortality to total mortality, has in-

creased about 73 per cent., over and above that for the years 1895, 1896, 1897, 1898 and 1899, and that the typhoid deaths in all towns and cities of over 4,000 inhabitants were about the same per population as those above given on the water-sheds of said three rivers during said time, and that on the ordinary basis of computing sanitary population by taking the aggregate population of all towns and cities of 4,000 or over, on the watersheds named, there was a population as follows:

On the Missouri watershed, 1,090,832.

On the Mississippi river above Grafton, 1,219,645.

On the Illinois river, exclusive of the sanitary district of Chicago, 385,305.

"State what, in your opinion, the sewage from 1,500,000 people of Chicago, discharged into the drainage canal, had to do with the increased death rate from typhoid fever in St. Louis as above stated."

"A. After carefully considering the question and the assumptions which it contains, and in view of my studies of the typhoid fever statistics of the city of St. Louis, to which I referred in my testimony of yesterday, as stated at that time, I believe that beyond all reasonable doubts the principal factor of the annual increase of typhoid fever mortality of the city of St. Louis since January 1, 1900, has been due to the pollution of the water supply of the city of St. Louis by the unpurified sewage of the sanitary district of Illinois."

This question and answer, like all of the testimony for complainant, assumes that for every effect there must be a cause, and in determining the cause, that most reasonable of belief,

and which most generally conforms to the experience of mankind must, of necessity, be adopted.

After a careful personal examination as to the life and conduct of typhoid bacteria in laboratory experiments, Dr. Ravold stated that, in his opinion, typhoid bacilli would live in the water passing from the city of Chicago to the city of St. Louis and remain sufficiently vitalized to produce disease when introduced in the city water supply; that, in his opinion, typhoid bacilli would live in this water for a period of from fifteen to thirty days. (Record, p. 7809.)

This opinion is in conformity with the general belief of sanitary scientists, based upon the most accurate, substantial and reliable data thus far obtainable, and this opinion and statement of Dr. Ravold is verified by the testimony of George C. Whipple, Prof. W. T. Sedgwick, George W. Fuller, Allen Hazen, and also by the admissions of all of defendants' expert witnesses, as has been elsewhere set forth in this brief.

Mr. Whipple was asked this question, which is of the same general character as the one propounded to Prof. Sedgwick, hereinbefore set forth:

> "Assume that between January 17, 1900, and December 31, 1902, as compared with the period from 1895 to 1899, inclusive, there had been no increase in the average of the number of deaths from typhoid fever in these cities situated on the Missouri river, the Mississippi river above Grafton, and the Illinois river and its branches, exclusive of the Chicago drainage district; and further assuming that the typhoid fever death rate in the city of St. Louis had increased 77 per cent, on an average during this period over the previous period mentioned; and further assuming that

there was no substantial change in the manner of treatment of the water supply of St. Louis; and assuming further, that since January 17, 1900, a large part of the sewage of Chicago had passed through the drainage canal, thence into the Desplaines, Illinois and Mississippi rivers and the intake, and assuming further that some of the water of the Mississippi river would contain a certain amount of the water of the Illinois river at the intake at the Chain of Rocks; state what, if anything, in your opinion, the Chicago sewage from the Drainage Canal had to do with that increased typhoid fever death rate in St. Louis?"

Mr. Whipple answered as follows:

"Under the assumption which you have mentioned, and if the conditions named there obtained, it is my judgment that the sewage of Chicago was the most probable cause of the increase of typhoid fever in the city of St. Louis, which you mention."

"Q. From your knowledge of the existing conditions in the Chicago Drainage Canal, and of the several water-courses between that canal and the intake tower of the St. Louis waterworks at the Chain of Rocks, is it or is it not your opinion that there exists any reliable and efficient natural agencies which can continuously insure the prevention of typhoid fever germs which may enter the Chicago Drainage Canal from reaching the intake of the St. Louis waterworks at the Chain of Rocks?

"A. It is my opinion that no such natural agencies exist."

Mr. George W. Fuller, at page 2608, stated:

> "That as a general proposition it is my judgment that the best index of the sanitary character of the public water supply is the mortality record from water-borne diseases in a community using the water supply in question, and especially the mortality statistics of typhoid fever."

After stating that, from his examination of the mortality statistics of the city of St. Louis, he had found that there had been an average increase of mortality from typhoid fever since the opening of the Drainage Canal, as compared to the period immediately prior thereto, and that such increase amounted to about 73 per cent, in passing upon the cause of this increase, Mr. Fuller said:

> "I ascribe it to an increased amount of infection in the public water supply, and I predicate this opinion upon the practically uniform distribution of the homes and residences in which typhoid deaths occurred in the city of St. Louis, and the further fact that a careful examination of several other possible sources of typhoid fever shows that no substantial portion of this increase may be explained in that way. (Record, pp. 2611-13.)

In speaking of the cause of the increase in typhoid in St. Louis, Mr. Fuller, at page 2614 of the Record, further said:

> "I am generally familiar with the typhoid fever statistics in the large centers of population upon the Missouri river watershed above the Chain of Rocks, Intake Tower of the St. Louis Waterworks, and, ex-

cluding the sanitary district of Chicago, during the period mentioned in the question. During these periods there have been, at quite a number of points, some variation in the amounts of typhoid fever prevailing in different years. Taking the typhoid fever statistics upon this watershed area, as stated, as a whole, but excluding the Sanitary District of Chicago, based upon the average number of deaths from typhoid fever every year, it is my judgment, viewing the matter as a general proposition, that there has not occurred on the natural area of the Mississippi river watershed above St. Louis an increase in the number of deaths sufficient to explain, to any material degree, the less safe condition of the Mississippi river water, as taken from the intake tower of the St. Louis waterworks during the last period as compared with the period from 1895 to 1899."

"Q. I will get you to state, Mr. Fuller, if you know of any cause that renders the water, if it is, less safe at the Chain of Rocks now, and within the last three years, than prior to January, 1900.

"A. In my judgment, it is the Chicago Drainage Canal discharging the sewage and drainage containing filth and infection from the city of Chicago which makes the water, in its raw condition at the intake tower at the Chain of Rocks, of the St. Louis Waterworks, less safe than it was during the period preceding January 1, 1900." (Record, pp. 2613-14 and 15.) See also Hazen's testimony, p. 2799.

XI.

BY THE CONDUCT OF DEFENDANTS IN DISCHARGING THE SEWAGE OF THE CHICAGO SANITARY DISTRICT INTO THE DRAINAGE CANAL THE WATER SUPPLY OF ST. LOUIS HAS BEEN INJURED.

The fact that typhoid fever has increased in St. Louis since 1900, with no known local cause other than the condition of its water supply, is conclusive evidence that the water has been subjected to infectious material, and that such infectious material was discharged into it at some point above, so that pathogenic bacteria might, in their travel down the river, reach the city of St. Louis before perishing or disappearing from the water.

After a careful study of local conditions, and the character of the water prior and subsequent to the opening of the drainage canal, Mr. Fuller, at pp. 2608-9, said:

> "It is my judgment that the water supplied to the citizens of St. Louis by the municipal water department during the years 1895 to 1899, inclusive, was what might be called a good sanitary water. I base that judgment upon this fact. During the period mentioned the typhoid fever mortality statistics showed as low a rate, approximately speaking, as in the case of quite a number of other American cities having a pure, or very nearly pure water supply."

And again, at p. 2613, in speaking of the condition of the water since the opening of the drainage canal, Mr. Fuller said:

> "I consider that the sanitary character of the public water supply delivered to the consumers in the city of St. Louis since January, 1900, has been less safe than it was formerly. * * * It is my judgment that it can not be classed as a good water."

Prof. Sedgwick, pp. 2202-3, that, from his examination of the statistics, which he had carefully studied, covering not only the city of St. Louis, but various cities throughout the United States, he found that from 1895 to January, 1900, the water supply for the city of St. Louis is shown to have been fairly good, and equal, if not superior, to that of Boston, which ranks among the cities of the country as having a good water supply; but that such conditions did not exist subsequent to January, 1900, as shown by the increase of typhoid deaths in the city. The cause of this change in the sanitary condition of the water at St. Louis is stated by Prof. Sedgwick, as follows:

> "After a careful consideration of the subject, I can say that, in my opinion, beyond a reasonable doubt, the principal portion of the increase of typhoid in St. Louis since January, 1900, and the principal annual increase since January, 1900, has been due to the infection of the water supply of St. Louis by the sewage of the Sanitary District of Chicago." (Record, p. 2214.)

The fact that the water supply of St. Louis has become inferior since the opening of the drainage canal is conclusively shown by the evidence of the increase of typhoid fever in that city since said date, heretofore set forth and referred to in complainant's original brief.

XII.

THE ADDED INFECTIOUS CONTENTS OF CHICAGO SEWAGE TO THE WATERS OF THE MISSISSIPPI RIVER AT ST. LOUIS INCREASE THE COST OF CONSTRUCTION AND OPERATION OF A FILTRATION PLANT, SUCH AS WOULD PROPERLY PROTECT THE PEOPLE OF ST. LOUIS AGAINST INFECTION BY PATHOGENIC BACTERIA.

The point was raised by defendants, during the taking of testimony, that it was necessary for the city of St. Louis to filter its water in order to obtain a perfect supply. Testimony in this respect was first injected into the case during the cross-examination of Prof. Sedgwick. (Record, p. 2381.)

Complainant objected to testimony of this character, for the reason that, even though the water supply of St. Louis was infected to some extent and filtration was necessary in order to guarantee a perfect water supply, the city of Chicago had no right to contribute to such infection, or to hasten the time when such filtration would become absolutely essential.

The city of St. Louis had the right to use the water in its natural condition, and to so preserve it.

We still insist that this testimony is irrelevant, and has no bearing upon the questions involved in the case. However, after defendants had seen proper to introduce testimony of the character just mentioned, it was not improper that complainant should show to the court that in the construction and operation of a filtration plant at St. Louis the cost and operation would be increased on account of the added infectious material coming from Chicago.

In this connection Prof. Sedgwick, at pp. 2382-3-4-5 and 6, testified as follows:

"Q. Now, Professor, in your cross-examination, one of the first questions that was asked you was with reference to whether it would cost any more to filter the water supply of St. Louis, after the opening of the drainage canal and now, under present conditions and those that existed then, than it would have cost before, and I want to ask you what you have to say about that proposition now, considering your answer as given then and the state of facts as they exist.

"A. The question as I remember it was in regard to purification by filtration, and my answer was that the cost would probably not be materially increased by the addition of the pollution and infection derived by the city of Chicago or the opening of the drainage canal. On reflection, however, I realize that I did not take into consideration with sufficient care the fact that aside from the masses of filth that might be washed down on certain occasions, such as freshet period, and which would add somewhat to the cost of the cleaning of the filter and caring for the same—a cost which might or might not be a material increase, in the conduct of those filters, according to the importance attached to the word 'material'—there is and would be the necessity for a much keener watch of the filters in regard to protection of operation so that it might make a difference; for example, between the employment of a low-salaried man and a high salaried man as resident manager of the works. The fact is that in all our big cities using water filters, although at first it was

thought that almost anyone could manage them, and low-priced men were often put in charge, experience is rapidly teaching us that the best men are none too good to supervise filters and safeguard the citizens against the incoming of the germs of infectious diseases. The volume of water passing through is so large that possibilities of damage by frost, to the filtering material, and the possibility of channels working through the filters, and various other factors are making it every day more and more clear that we have got to have able and experienced and high priced men in charge of these things, so that even at present I do think there would be a material increase of cost in the probable management of such filters, because of the added pollution and infection from the city of Chicago. This is more particularly the case at present because there either is now or lately has been in the city of Chicago a typhoid fever epidemic, the number of deaths in 1902 having been larger than at any time since the great epidemic of 1890, 1891 and 1892. The actual occurrence of such an epidemic at the present time, or very lately, would of necessity be a source of the greatest solicitude on the part of anyone operating filters in St. Louis during or shortly after any such epidemic, and it would be necessary to employ extraordinary care in operation and supervision of such filters even at the present time, because of the epidemical condition of typhoid fever in Chicago in 1902. Furthermore, inasmuch as Chicago has repeatedly suffered from outbreaks of the disease which can be fairly called, and have been called epidemics, the present operation of filters in the hands of any competent per-

son would require extraordinary and constant attention and skill; and such things are costly.

"Q. Well, can you state whether or not there might in the future arise a condition by reason of the increase of population in Chicago to say, three or four million people that a single filtration would not suffice?

"A. I think I have already intimated in some part of my testimony—I have already expressed in some part of my testimony an opinion to that effect, and in consideration of the already large amount of typhoid fever in the Sanitary District or city of Chicago, and in view also of the rapid increase of population in that city, I should expect that such cost of maintenance and operation of filters as has just been referred to, might steadily increase until it might even become necessary to resort to double filtration. Looking still further into the future, there might even come a time when at low period of flow the oxygen in the river should disappear altogether for brief periods, and septic conditions should arise, and new difficulties in filtration be introduced, not necessarily by the typhoid fever alone, but by the presence of mere filth which should so corrupt the stream as to render the water unfit for drinking purposes under any consideration. This, of course, would probably be a very long time in the future, but it is entirely within the bounds of possibility. Many a stream that was once bright and pure has been converted into an open sewer, a stinking nuisance, not only unfit for drinking purposes, but a source of obnoxious odors and the like; as for instance happened in the Blackstone river, in the State of Massachusetts,

which was formerly a bright, pretty stream, but which has been so defiled by the sewage of the city of Worcester that between Worcester and the town next below—Milbury by name—it is simply an open sewer; or has happened, I suppose, in the little stream in St. Louis, known as Des Peres, which anyone can see is now practically an open sewer, but which was presumably a few years ago a decent stream. It seems to me that it is precisely these long looks into the future that we have got to take into cases of this kind. The population on the Missouri and Mississippi is rapidly growing, the defiling of the rivers is increasing and likely to increase because of their growth, and the addition of a vast population, like that of Chicago, discharging its filth into the Illinois river, a tributary of the Mississippi, and contributing to that general deterioration of the river, is bound to go on unless some steps are taken to correct it, is a matter, it seems to me, of grave consequence, and likely to add a heavy financial burden to any city using its water. I may say still further in regard to the Blackstone, the history of which is very interesting in this connection and important, that while the Blackstone river is furnished with various dams which were formerly sources of water power, these are gradually filling up, and although at times the water flowing over them is very clear, at flood times it is black and dirty, and the river flushing itself to a certain extent, removes these impurities and puts them further down, but has thus far failed to come anywhere near to purifying itself in the upper reaches, and is, of course, not used as drinking water below. The stream has been turned from a respectable river

into a most objectionable and abominable open sewer between Worcester and Milbury. Bearing in mind, furthermore, that the dry water flow, the low water flow of the Mississippi river at St. Louis, is something like 40,000 to 42,000 cubic feet a second; and that Chicago is already pouring down 5,000 cubic feet a second of mixed water and sewage, and that the drainage canal is built in places for the carriage of at least 10,000 cubic feet a second, it seems to me fair to inquire what will be the effect of that mixture of 10,000 feet a second of water and sewage with the Mississippi river, which at times is only flowing 40,000 to 42,000 cubic feet a second in volume at St. Louis. Here we come, it seems to me, near to the danger line. It is not at all inconceivable that, all things considered, when 10,000 cubic feet a second are poured down and are more readily charged at Chicago with mere pollution —quite aside from typhoid fever—the presence of this material in the Mississippi, itself growing more polluted meanwhile, may bring about, or help to bring about at certain seasons of the year, a condition approaching that of a septic tank, when the oxygen will begin to fall off in the water, and that water will begin to degenerate into a condition of dilute sewage. All these large and general propositions, it seems to me, have got to be kept in mind. I think they involve added cost today, and I think they will involve a very greatly increased cost in the near future, and they may even amount, within fifty or a hundred years, to such a pollution of the Mississippi river in dry weather times, low water times, as to make it an impossible source for any modern, civilized city; for it is fair to

suppose that cities in the meantime will not relax their sanitary requirements as to water supply, these having been steadily rising, so that even double filtration in time may not suffice. In regard to the probable number of cases of typhoid fever in Chicago during the last three years, as compared with the number in the cities on the rest of the watershed during the same period, and in regard to the number in the cities before the opening of the drainage canal, above the intake of the chain of rocks, I am deeply impressed with the fact that while I have been able to learn of only about 11,000 cases in the cities on the watershed during each of the three year periods referred to, before and after,

"Q. During each or during the total?

"A. During each of the three year periods—above the chain of rocks and exclusive of the sanitary district of Chicago—I find that there must have been about 16,000 cases in Chicago during the period of three years since the opening of the drainage canal; so that it appears that the opening of the drainage canal has more than doubled the probable number of typhoid fever cases in the urban communities on the watershed above the intake at St. Louis. Moreover, although Chicago is 358 miles distant from the city of St. Louis, some of the cities on the Missouri and Mississippi watersheds are even farther away, many of them, perhaps, farther away. When I consider all of these facts taken together, I cannot escape the conclusion that the opening of the drainage canal was a very grave addition to the sanitary and financial burdens of the people of the State of Missouri using the Mississippi river below Grafton."

Mr. Fuller, at pages 2623 and 2624, testified that the increased amount of infection coming into the Mississippi river from Chicago produced an added responsibility, both as to the construction of a filtration plant and its operation. The testimony of Mr. Fuller in this connection is, in part, as follows:

> "A. In my judgment the increased amount of infection coming into the Mississippi river from the city of Chicago's sewage at the present time makes an added responsibility as regards the treatment of that water, to make it perfectly safe and wholesome to the citizens of St. Louis. Such treatment of the water would involve, I think, at the present time, more responsibility, and in a financial way it would be shown by the greater expense of supervision of a filtration plant, and the added cost of supplies used in connection with the operation of filtration works, especially at times of low water. It would also mean that such filtration works, if adopted, would be operated from time to time, if not regularly, at lower rates of filtration than if this increased infection were absent. The significance of this is that by reducing the rate of filtration that a larger plant would be required, and hence a more expensive installation for filtration works, to purify the same quantity of water than in the instance of water without this added infectious material. 'Looking some distance into the future and considering the various centers of population naturally tributary to the Mississippi river at St. Louis, the Missouri and Illinois, but excluding the Chicago Sanitary District, it is certain that there will ultimately come a time when single filtration can hardly be expected to

produce a satisfactory quality of water with its source at the Chain of Rocks intake tower. When that time will come it is difficult to state specifically, as it will depend upon the rate of growth of population in the communities situated upon the watershed of the Mississippi, Illinois and Missouri rivers, exclusive of the Sanitary District of Chicago. Whatever the rate of growth may be in the communities situated upon the watershed of the Mississippi river above St. Louis, independent of the city of Chicago, it is certain that the added infection of the Mississippi water at the St. Louis intake, due to the Chicago sewage, will hasten the day when single filtration at St. Louis will prove unsatisfactory, and when it will be necessary to give attention either to double filtration, or to other methods involving increased expense, and increased responsibility."

Dr. Herbert E. Smith, at page 7723, stated:

"Taking into consideration the facts which you have called to my attention, I would state it as my opinion that the installation and operation of a filter plant at St. Louis would be more expensive, by reason of the discharge of the sewage of Chicago into the Illinois river, and that if the deleterious agents of the sewage were removed, that the cost of installation and maintenance of a filter plant at St. Louis would be lessened."

John W. Alvord, at page 7791, stated:

"The design and construction of a purification plant dealing with seriously polluted water, especially

one of known high typhoid pollution, should be more complete and delicately adjusted to its work than one dealing only with water of rare infection, and presenting less dangerous difficulties, such as turbidity and color."

Mr. Alvord further stated that in the event the water became more thoroughly subjected to infectious material double filtration should be employed; that it should take the form either of double filtration or have complete sedimentation in more than one stage, followed by most careful filtration. That double filtration had been resorted to in several places in Germany, and recommended at Springfield, Mass., by George W. Fuller and Samuel Gray, and is now being introduced into the new filtration plant at Philadelphia by John W. Hill, in which last case they are proposing to pass water of known typhoid infection through what they call preliminary filters as a first stage, and then through slow sand filters as a second stage.

"Q. Would such method be more expensive than single filtration?

"A. It would. It is my opinion that it would very greatly increase the cost of filtration, both in its first construction and its operation."

In reference to the increased cost of construction and operation of a filtration plant at St. Louis, such increased cost being attributable to the infectious material coming from Chicago, Mr. Rudolph Herring, one of defendants' witnesses, testified as follows:

"Q. In the construction of a filtration plant, do you, as a sanitary engineer, take into consideration the source of pollution or infection by substances dele-

terious to the public health in the construction of the plant, which substances and sources of pollution exist upon the river above the point where the water is to to be filtered?

"A. I always take those matters into consideration, and have, in some instances, made what is called a sanitary survey of the entire watershed which yields the water to be used.

"Q. In the event a filtration plant was established for the purpose of filtering the water of a certain city, and that at some point above that city a typhoid epidemic should be prevalent, why has it been necessary for the management of a filtration plant to use extra precautions during such epidemic?

"A. The running of a filter plant, like the running of any plant, can be somewhat variable, owing to the fact that human beings are required to take care of the management. When there exists a special danger, in that instance, as well as at all other instances where danger threatens a community, or a smaller body of persons, extra precautions are taken to avoid anticipated possible trouble. It is quite natural, therefore, that if I should manage a filtration plant myself I should give the orders myself that if a known epidemic exists there should be every reasonable caution taken for special care to be exercised during that period."

"Q. Is there an artificial filtration plant in existence which removes 100 per cent. of the bacterial contents of water?

"A. In the records which are published, and which I have seen, there are not infrequent ones where

the bacteriological results give the removal of 100 per cent. of the bacteria.

"Q. What is the cause in the variation in the percentage of bacteria removed by filtration plants?

"A. The cause is both to be sought in irregularity of construction and irregularity of operation. It is impracticable, if not impossible, to make a perfect construction, and it is likewise impracticable to demand of the average laborer or artisan or inspector or superintendent an absolute adherence to perfect conditions.

"Q. And as the degree of precaution in the management of a filtration plant increases, so also the percentage of absolute removal of bacterial contents in the water is approached.

"A. Theoretically, I admit the truth of that position, but practically, I should say that in the ordinary operation of filtration works, particularly through Europe, where they have been managed for so many years, so far as we know, typhoid fever germs have been entirely excluded. The remnant of cases that still appear in those cities is due to other causes than those of water-borne pollution. It has been found in Europe, as well as in this country, that after the introduction of filter plants the typhoid fever rate has dropped to about one-fourth of the rate that previously existed, some cities more, some cities less.

"Q. Those cities to which you refer have slow sand filtration, have they not?

"A. They have. My personal opinion, not speaking for the profession in general, when the water is

highly polluted and infected I should prefer the slow filters to the rapid filters, for the reason that the chances for infection passing the slow filter would be very much reduced as compared with the chances in passing through a rapid filter—for the same reason that I would rather be on a slow moving train than upon a rapidly moving train if this train met with an accident. It is always possible in any public work to have something go amiss, although we try to make such works, upon which not only a large expense, but also the health of the people depends, as nearly as practicable what we call "fool proof."

"Q. Slow sand filtration plants are more expensive, are they not?

"A. The facts are these slow sand filters almost invariably cost more to build, but less to operate than the rapid or mechanical filters." (Record, p. 7035.)

Mr. John W. Hill, at pages 7571 to 7573, inclusive, stated that the degree of infection in water would affect the grade of sand used in charging the filters with filter material; that if the source of supply is known or believed to be materially infected, it should call for greater care and vigilance in the operation of the filters. That is to say, if filtration has for its object the removal of material reduction of sewage pollution in the water, it would require denser beds of sand and more care in the operation of the plant than if the sole purpose was to remove suspended matter not of a deleterious character. That the result would be to reduce the size of the sand in the bed, that is to say, it would be a denser bed, but not quite so coarse, and would demand closer attention on the part of the filter manager, who should keep in touch with the daily operation of the filters; that the result would be as you reduce the size of the grains of sand

and employ denser bed of sand, the slower the process of filtration becomes; that it is true that water would percolate through rough grains of sand more rapidly than through dense grains of sand; that the rate of percolation will be more rapid in the more porous beds of sand, and as the degree of diminution in the character or size of the sand grains, the slower the process of filtration upon a given area.

From the foregoing statement of Mr. Hill the only natural deduction that can be made is that, by reason of the greater infection, larger quantities and denser beds of sand are required than if the water to be filtered be subject to less infectious material; and that the employment of such dense beds of sand necessarily means a greater expenditure of money in construction, because a greater quantity of material is employed, and also greater care and precaution in the operation of the plant.

We deem it scarcely necessary to discuss this proposition at length, for the reason that it is a natural conclusion that as infectious material increases in the water supply the facilities used for the purpose of removing such material from the water must necessarily be more expensive, and the cost of operation increased. In fact, the more difficult the task of removing the infectious material, the more expensive it must necessarily be.

In conclusion, we submit that, according to the evidence, complainant is entitled to the relief asked. Taking the testimony in its entirety, considered in the light of experience and reason, and giving it a practical application to the questions of controverted fact, the dangerous and damaging effect of the Chicago sewage on the public health of St. Louis is clearly shown.

The increase in typhoid deaths in that city is established, and the cause of the increase is from the testimony traceable only to the infectious material contained in it coming from the sewers of Chicago.

The increase in typhoid deaths at St. Louis being established, and no adequate cause therefor existing either locally or throughout the entire watershed of the Mississippi, Missouri and Illinois rivers, exclusive of Chicago, the natural and only conclusion that can be arrived at is that such increase in typhoid at St. Louis was unquestionably caused by the conduct of defendants in permitting the sewage of the Sanitary District of Chicago to be discharged into the Drainage Canal.

Respectfully submitted,

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IN THE

Supreme Court of the United States.

OCTOBER TERM, 1905.

STATE OF MISSOURI, *Complainant,* *vs.* **STATE OF ILLINOIS and the SANITARY DISTRICT OF CHICAGO,** *Defendants.*	**ORIGINAL NO. 4.**

COMPLAINANT'S STATEMENT, BRIEF AND ARGUMENT

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STATEMENT.

This is a proceeding in equity, instituted on the 17th day
1 of January, 1900, by complainant, the State of Missouri, against defendants, the State of Illinois and the Sanitary District of Chicago.

The Sanitary District of Chicago is a "public corporation," organized under the laws of the State of Illinois and located in part in the city of Chicago, and in the county of Cook, in the State of Illinois, and is a citizen of the State of Illinois.

The remedy asked for is an injunction against defendants, restraining them from receiving or permitting sewage to be re-

ceived or discharged into the artificial channel or drain con-
2 structed by the Sanitary District of Chicago as hereinafter explained; under authority derived from the defendant state, in order to, and for the purpose of carrying off and discharging the sewerage of Chicago in the Mississippi River a short distance above the city of St. Louis.

Prior to the construction of this canal, the sewerage of Chicago has been discharged by way of the Chicago river into Lake Michigan, while since the opening of the drainage canal by defendant, the Sanitary District of Chicago, the sewage of the city has been caused to flow therefrom through the canal into the Des Plaines river and from thence into and down the Illinois river, passing into the Mississippi river at Grafton, a small town situated upon the Mississippi, thirty-two miles above the intake of the St. Louis waterworks.

The bill of complaint alleges that the nature of the injury complained of is such that an adequate remedy can only be found in the Supreme Court of the United States, at the suit of the complainant.

The substantial purpose of the complaint is to subject the public work of the construction and operation of the drainage channel constructed from the Chicago river at Chicago, southwestwardly to, and connecting with, the Des Plaines river at Lockport, a point immediately above the city of Joliet, to the court's supervision, upon the charge that the method of construction and operation or maintenance creates and constitutes a continuing nuisance, dangerous to the health of the people of the State of Missouri; that the operation of the canal on the part of defendants, if not restrained, results in the daily transportation, by artificial means, and through an unnatural channel, of large quantities of undefecated sewerage, and of accumulate deposits in the harbor of Chicago, and in the bed of the Illinois

river, which poisons the water supply of the inhabitants of Missouri and injuriously affects that portion of the Mississippi river which lies within complainant's jurisdiction.

No attack is made upon the canal or artificial channel as an unlawful structure, nor is any attempt made to prevent its use as a waterway. Complainant seeks relief against the pouring of undefecated and unpurified sewage and filth through it by
3 the artificial arrangements into the Mississippi river to the detriment of complainant and its inhabitants.

The language of the bill is as follows:

"The complainant, the State of Missouri, and one of the states of the United States, brings this, its bill of complaint, against the state of Illinois, one of the states of the United States, and the Sanitary District of Chicago, a public corporation, organized under the laws of the state of Illinois, and located in part in the city of Chicago, and in the county of Cook, in said state of Illinois, and a citizen of the state of Illinois.

"And your orator complains and says that it is a state containing a population of upwards of three millions of people, and lying on the west bank of the Mississippi river, a public, navigable and running stream, and having a frontage on said stream of over four hundred miles.

"And your orator shows that by the act of Congress providing for the organization and admission of Illinois and Missouri as states of the Union, it was declared that the western boundary of Illinois and the eastern boundary of Missouri should be the middle of the main channel of the Mississippi river, that the shores of the Mississippi river, where its waters form the Missouri and Illinois boundary, and the soil under the waters thereof, were not granted by the Constitution of the United States, but were reserved to the states of Illinois and Missouri, respectively.

"And your orator shows that the states of Missouri and Illinois each have concurrent jurisdiction over the waters of the Mississippi river forming the boundary between them, and each of said states has exclusive territorial jurisdiction over that portion adjacent to its own shore, and your orator shows that the Illinois river empties into the Mississippi river at a point above the city of St. Louis, on the Illinois side of said Mississippi river.

"And your orator further shows that within the territory of your orator and on the banks and shores of said Mississippi river and below the mouth of the Illinois river are many cities and towns in the State of Missouri, and many thousands of
4 persons who are compelled to and do rely upon the waters of said river, in their regular, natural and accustomed flow, for their daily necessary supply of water for drinking and all other domestic and agricultural and manufacturing purposes, and for watering stock and animals of all kinds, and that said Mississippi river has been flowing in its regular course and has been used for the purposes aforesaid by the inhabitants of the said State of Missouri for a time whereof the memory of man runneth not to the contrary, and that said river and its waters and the use thereof for drinking, agricultural and manufacturing purposes, in their accustomed and natural flow, are indispensable to the life and health and business of many thousands of the inhabitants of the State of Missouri and of great value to your orator as a state.

"And your orator shows that cities and towns below the mouth of said Illinois river, within the territory of your orator, do and are compelled by means of waterworks, water towers and intakes, built and constructed for that purpose, to supply the inhabitants of said cities and towns with an adequate supply of pure and wholesome water, fit and healthful for drinking and

all other domestic purposes and uses, from the said Mississippi river so flowing in its ancient, accustomed and natural course.

"And your orator shows that said waterworks systems are constructed with reference to said Mississippi river and for the purpose of taking water therefrom and not from any other source.

"And your orator shows that heretofore, to wit, in 1889, the state of Illinois enacted a law, known as the Sanitary District Act, together with an act for the improvement of the Illinois and Des Plaines rivers, and that under said act of said state the said corporation, known as the said Sanitary District of Chicago, was organized and is now existing and operating, and that by express terms of said act any canal or drain corporation organized in accordance with its provisions may have conditions, restrictions or additional requirements placed on said corporation, or the act authorizing the creation of said corporation may be amended or repealed, and that by the express provisions of said act, before any water or sewage shall be admitted into any channel constructed under said act, the trustees of said channel shall notify the Governor of Illinois of the completion of said channel, and the Governor of Illinois shall appoint three commissioners to examine said canal or channel, and report to the governor if the same complies with the act of the state of Illinois; and if it does, the governor shall authorize the water and sewage to be turned into said channel; and that without the said permit it can not be so turned in; and that by the general provisions of said act said channel is at all times subject to the control and supervision of the state of Illinois and her authorities.

"And your orator further shows that the Chicago river is situated in the basin of Lake Michigan and has two forks or branches flowing through the city of Chicago and into Lake

Michigan, and that the natural drainage of Chicago, Illinois, is into Lake Michigan, and the sewage and drainage of the territory embraced in the defendant's district, the Sanitary District of Chicago, is led into or flows into the Chicago river and Lake Michigan.

"And your orator further shows that the defendant herein, the Sanitary District of Chicago, with the authority of the state of Illinois, and acting as a governmental agency of said state, and under the supervision and control and subject to the approval of the state of Illinois, has constructed a channel or open drain from the west fork of the south branch of the Chicago river, in the city of Chicago and county of Cook, in the state of Illinois, to a point near Lockport, in the county of Will, in said state, where said channel or drain connects with and empties into the Des Plaines river, which empties into the Illinois river, and which latter river flows and empties into the Mississippi river at point distant about forty-three miles above the city of St. Louis, Missouri.

"And your orator further states that the channel built by the Sanitary District of Chicago was so built by said Sanitary District as one of the governmental agencies of the State of Illinois, and by the pretended lawful authority of said state, and under the direction, supervision and control and governmental power of the state of Illinois, which said state has heretofore at all times sanctioned and now, through its governor and other officers, sanctions the building of said channel and opening thereof.

"And your orator further shows that in the construction of said channel or drain the defendant, the Sanitary District of Chicago, Illinois, cut through the natural ridge or watershed, which divides the basin of Lake Michigan from the basins of the Des Plaines and Illinois rivers and the basin of the Missis-

sippi river, and that having so constructed said channel and having about completed the same, and having, under the supervision of and with the sanction of the state of Illinois, extended said artificial channel through said natural divide of the watershed, the defendants now propose and threaten to receive into said channel or drain the sewage matter and filth of the Sanitary District of Chicago, which embraces nearly the whole city of Chicago and a portion of the county of Cook, and, without any legal authority so to do, has already in part effectuated its said threat and purpose and threatens to permit and to cause said sewage and filth, by artificial means of pumping and otherwise, to flow through the channel or drain towards and into the said Des Plaines river and eventually into the Mississippi river, thereby, with the approval of and subject to the inspection and control and supervision of the state of Illinois, and by the pretended authority thereof, reversing the natural flow of said Chicago river.

"And your orator further shows that the sewage matter and poisonous filth which it is thus threatened to receive and to permit and to cause to flow through said artificial channel into said Des Plaines river is that which is created by a population of upwards of one and one-half millions of people, besides that which is created by a great number of stock yards, slaughter establishments, rendering establishments, distilleries and other business enterprises and industries lining both sides of the Chicago river, producing filth and noxious matters; all of which are there discharged into the said Chicago river or drained therein from the surface.

"And your orator further shows that for many years past
7 the said city of Chicago, the greater portion of which is embraced in the limits of the defendant corporation, the Sanitary District of Chicago, as aforesaid, has been discharg-

ing its sewage matter and filth into the Chicago river and into Lake Michigan in such large quantities that much of it has accumulated in the bed and along the sides of the river and upon the bed of said Lake Michigan, near the shores thereof, and that the plan threatened and attempted now to be adopted by the defendant, the Sanitary District of Chicago, acting in conjunction with and subject to the control of the defendant, the state of Illinois, and by the pretended authority of the said state of Illinois, will loosen said accumulated matter and filth, and will also direct it and cause it to flow towards and into said artificial channel or drain, and thence into said Des Plaines river, and finally into the Mississippi river and into the waters thereof within the jurisdiction and under the control of your orator and past the homes of the inhabitants of your orator and the towns and cities within the borders of your orator, and past the waterworks of said cities and towns within the State of Missouri.

"And your orator further shows that the amount of said undefecated filth and sewage and poisonous and unhealthful and noxious matters proposed to be, and now about to be, permitted to be turned into said artificial channel and through said Des Plaines and Illinois rivers into the Mississippi river from the said Sanitary District of Chicago by the defendants, acting jointly, will amount daily to about fifteen hundred tons, and that if defendants should be permitted to carry their said threats into execution, and should cause said above amount of undefecated sewage and other poisonous and noxious matters, which would otherwise flow into Lake Michigan, to flow into the Mississippi river, that the waters of the Mississippi river within the jurisdiction of your orator will of a certainty be poisoned and polluted and rendered wholly unfit and unhealthful for drinking and domestic uses, and will render wholly valueless and entirely worthless the various waterworks systems of towns and cities

on the borders of the State of Missouri, established and acquired at great cost and expense, and will deprive your orator, the State of Missouri, and its inhabitants, of the right to use the
8 waters of said river for drinking and all other domestic and manufacturing and agricultural purposes, as said water has been so used in its accustomed and natural flow heretofore for the length of time that the memory of man runneth not to the contrary thereof.

"And that said threatened action of the defendants will amount to a direct and continuing nuisance and be an interference with the use by your orator and its inhabitants of the waters of the Mississippi river flowing in their natural state, polluting and poisoning the same by the means aforesaid, whereby the health and lives of the inhabitants of your orator will be endangered and the business interests of said state will be greatly and irreparably injured, and which said damage to the lives and health and the business interests of said state resulting from said poisoning and polluting of said waters as aforesaid to your orator can not be estimated in money value.

"And your orator on information and belief states and charges the fact to be that said fifteen hundred tons of poisonous undefecated filth and sewage of said Sanitary District of Chicago will be daily carried through said artificial channel and sent through the Des Plaines and Illinois rivers into the Mississippi, and great quantities thereof will be deposited in the bed and soil of said river belonging to your orator and wholly within the jurisdiction thereof, to your orator's great and irreparable damage, and that the fifteen hundred tons of undefecated sewage and filth now about to be daily injected into the waters of the Mississippi river and into the portion thereof over which the State of Missouri has jurisdiction, and from which thousands of her inhabitants obtain drinking water, will pollute and

poison the said water of the Mississippi river to such an extent as to render it unwholesome and unfit and unhealthful for use for drinking by the said inhabitants in the territory of your orator and unfit for use for watering stock and for manufacturing purposes.

"And your orator further shows that great quantities of undefecated sewage turned into the Mississippi river in the manner and by the means aforesaid will poison and pollute said water with the germs of disease of various and many
9 kinds. And your orator further shows that the acts herein complained of on the part of the state of Illinois, acting in conjunction with one of her governmental agencies, the said Sanitary District of Chicago, will cause a continuing nuisance in the Mississippi river, and that the said state of Illinois has no power or authority to cause or permit or assist in causing the commission and continuance of a nuisance in the flowing waters of the Mississippi river, a navigable stream, to the detriment and irreparable and continuing damage and injury of the State of Missouri, and the continuing and irreparable injury to the lives and health of the citizens and inhabitants of the State of Missouri, and that unless restrained by the order and decree of this court the defendants, the state of Illinois and the Sanitary District of Chicago, acting together, will, in accordance with the terms of the act under which said Sanitary District is organized, under the permit and authority of the governor of Illinois and of the state of Illinois, turn said water and sewage aforesaid, by the manner and means aforesaid, into the Des Plaines and Illinois rivers, and thence into the Mississippi river, all of which your orator says and avers is contrary to equity and good conscience and would result in the manifest and irreparable injury of your orator and the health of her citizens in the premises, and your orator is wholly without remedy at

law and without any adequate remedy to prevent the flowing of said sewage as aforesaid, save by the interposition of this court.

"For as much as your orator can have no adequate relief except in this court, and to the end thereof, that the defendants may, if they can, show why your orator should not have the relief prayed, and to the end that the defendants may make a full, true, direct and perfect answer to the matters hereinbefore stated and charged, but not under oath, an answer under oath being hereby expressly waived, and to the end that the defendants, their officers, agents, servants and employes may be restrained by injunction issuing out of this court from receiving or permitting any sewage to be received or discharged into said artificial channel or drain, and from permitting the same to flow or causing the same to be made to flow through said channel or drain towards and into the Des Plaines river, your orator prays that your honors may grant a writ of injunction, under the seal of this honorable court, properly restraining and enjoining the defendants, the officers, agents, employes and servants of the Sanitary District of Chicago and the state of Illinois, from permitting or causing any of said sewage to be discharged into said channel or drain, and from permitting or causing said sewage and poisonous filth thence to flow into said Des Plaines river; that defendant, the state of Illinois, be enjoined and restrained from issuing to its co-defendant permission and authority to do and perform the acts aforesaid or to allow them to be done; and your orator also prays for a provisional or temporary injunction pending this cause, restraining and enjoining the several acts aforesaid, and for such other and further relief as the equity of the case may require and to your honors may seem meet.

"May it please your honors to grant unto your orator not only a writ of injunction conformable to the prayer of this bill,

but also a writ of subpoena of the United States of America, directed to the state of Illinois, the governor and attorney-general thereof, and to said Sanitary District of Chicago, its officers, trustees and agents, commanding them on a day certain to appear and answer unto this bill or complaint, and to abide such order and decree of the court in the premises as to the court shall seem proper and required by the principles of equity and good conscience."

On the day the bill was filed the dam at the controlling works, near Lockport, was lowered and the unpurified sewage and filth from Chicago started on its journey down the Des Plaines, Illinois and Mississippi rivers. Since then it has been constantly and continuously operated by defendant Sanitary District of Chicago without hindrance or interruption.

Defendant filed a demurrer to the bill, which was argued on November 12th and 13th, 1900. The court delivered its opinion thereon on the 28th of January, 1901.

Defendants were thereupon given time in which to answer. The answers were filed on the.....day of....., 1901.

Whereupon Frank S. Bright, Esq., of Washington, D. C.,
11 was appointed commissioner to take the testimony and return the same into court.

The taking of testimony was commenced on the 17th day of February, 1903, and continued at intervals till May 28, 1904, when it was completed.

During the time above mentioned witnesses were examined on the part of complainant at St. Louis, Mo., and Washington, D. C., while testimony on behalf of defendants was taken at Chicago, Peoria, Peru, LaSalle, Ottawa and Morris, Illinois, at Baltimore, Md., and Philadelphia, Pa.

A trip of two weeks was made up the Illinois river on a steamboat by the commissioner, on which testimony was taken

at Grafton, Hardin, Pearl, Gravel Point, Meridosia, Beardstown, Kampsville, Pekin, Chiticochie, Henry and other points on the river.

For many years prior to 1895 the city of St. Louis derived its water for drinking, domestic and manufacturing purposes from the Mississippi river at a place known as Bissel's Point, about two and one-half miles north and above the "Eads bridge" which spans the river at the foot of Washington avenue; Washington avenue extending east and west in such way as to pass practically through the heart of the city dividing it into two approximately equal parts. To further identify and locate Bissel's Point, so that it may be easily and readily understood, it will be known that the present "Merchants' bridge" crosses the river about two hundred yards below and south of the intake (now abandoned).

The intake extended from the bank of the river into the water about one hundred feet, except in exceedingly low stages of the river, when the water receded entirely from it. In order to secure ample water during such times a flexible pipe was used which was carried out into the stream and water drawn through the pipe by means of a low pressure pump. Under such conditions the intake was abandoned.

Large reservoirs were constructed near the intake and the water being pumped into them was afterwards distributed throughout the city for use.

In 1892 a severe typhoid epidemic occurred in St. Louis,
12 which raised the total typhoid deaths in the city from one hundred and sixty-six occurring in 1891, to four hundred and eighty-eight in 1892. This large increase in typhoid received the attention of the health authorities of the city and was thoroughly investigated by public officials having in charge the city's water supply, and by the local physicians. Harlem

creek passes through a portion of the city and empties into the Mississippi now about one thousand feet above the intake at Bissel's Point. A number of cases of typhoid fever developed in the locality drained or sewered by Harlam creek. Soon after the existence of these cases, typhoid became most prevalent throughout the city. In the course of a few weeks it became epidemic. This condition, as above stated, brought about an investigation. It was found that the sewage from the creek above named flowed out into the river passing down and into the intake. This, on account of the difference in the water, was readily observable to the investigators. In fact, was plainly visible to any one standing on the bridge connecting the intake with the reservoirs. In order to relieve the situation a dam was constructed across Harlem creek at its mouth and a pump used to convey the water from the creek to a place below Bissel's Point where it was discharged into the river. This was done to prevent a contamination of the water supply. The effect of this change in conditions manifested itself at once, the result being that within a short time deaths from typhoid had become reduced to the normal condition. Thus we have a very striking example of the effect produced upon the people of a city who drink and use their own sewage. In other words, the effect of a sewage polluted water upon those who use it for domestic purposes.

This discovery brought the people of St. Louis to a realization that the city had become so extended in populous territory that the intake at Bissel's Point was located in an undesirable place, a large part of the people residing north and above the intake and sewering either directly into the river or into Harlem creek and from thence into the river above Bissel's Point. In fact, the water supply, once reasonably safe, was, on account of

the growth of the city, found to be seriously infected with
13 disease producing organisms.

The city being driven to make a change in its water supply finally determined to abandon the intake at Bissel's Point and construct a new plant at Chain of Rocks. This was done, the new plant being put in operation in the latter part of 1894.

Chain of Rocks is located on the Mississippi river eight miles above Bissel's Point or about ten and one-half miles above Eads bridge. At this point a tunnel, constructed of masonry, is extended into the river about 1,500 feet from the shore. At the end of the tunnel in the current of the river is a tower connected with the tunnel. This tower is known as the "Intake Tower" of the St. Louis Waterworks. From the tower to the Missouri shore of the river is a "chain of rocks" so constructed as to deflect the water from the Missouri shore causing a swift flow to pass down around the tower. From this rock constructed dyke the place derives its name, "Chain of Rocks." The tower contains openings down through which the water passes into the tunnel. From the tunnel it runs into the uptake reservoir, from whence it is pumped into large reservoirs, six in number. The water is allowed to remain in those large reservoirs about 36 hours. It then passes out into a conduit and is carried south and west to Baden, a distance of about six miles, where by the use of high service pumps, a portion of it is drawn into what is known as the high service tower, located on Grand and Lafayette avenue. From this tower the western and central portions of the city are supplied with water. The remainder of the water passing through the conduit to Baden is diverted into the old reservoirs at Bissel's Point, and from these reservoirs, by the use of low service pumps, the central and low parts of the city are supplied. The foregoing constitutes the St. Louis Waterworks system as it is today, and as it has been since the

removal of the intake to Chain of Rocks from Bissel's Point in 1894. The only treatment afforded is to allow the water to stand in the reservoirs from 24 to 36 hours before distributing it to the people. Since the removal of the intake to the Chain of Rocks there has been no change in the manner or character of treatment.

The Missouri river enters the Mississippi about 8 miles
14 above "Chain of Rocks," and the Illinois finally joins with the Mississippi about 24 miles from the mouth of the Missouri, or 32 miles above Chain of Rocks. With St. Louis, the metropolis city of the State, with a population of almost one million, situated upon the Mississippi river immediately below its confluence with the Illinois and Missouri rivers, and with the Mississippi as its only possible available source of water supply, it is essential to the State of Missouri to guard well the sanitary condition of this stream and protect it as far as possible from the damaging effect of sewage pollution and infection of cities, districts and communities situated upon neighboring watersheds.

Ascending the Missouri river, we find a large body of water draining an extensive area of territory of 520,000 square miles, comparatively thinly populated. The urban population on this area of watershed being 1,090,832, according to the census of 1900, taking into consideration all towns and cities having 4,000 or more inhabitants. This river constitutes the natural drainage basin or channel of a very extensive portion of the central western part of the United States, consisting in parts of Missouri, Kansas, Iowa, Colorado, Nebraska, Montana, North and South Dakota and Wyoming. It also claims a large part of the British possessions as belonging to its drainage area.

The area of the Mississippi river watershed above the mouth of the Illinois river at Grafton is 286,535 square miles, having an urban population of 1,219,645. This drainage area covers a

portion of the following states: Missouri, Illinois, Iowa, Minnesota, Wisconsin, North and South Dakota.

The area of the natural watershed of the Illinois river is 32,081 square miles, covering a portion of Illinois, Wisconsin and Indiana.

The urban population of the natural watershed of the Illinois river is 385,305. The urban population of both the Mississippi and Illinois watersheds being based upon the total number of inhabitants residing in towns and cities of 4,000 and over.

The total urban population of the Mississippi above St. Louis, including the Missouri and Illinois rivers, is 2,695,782, with a combined drainage area of 838,616 square miles.

The Missouri river has 496,919 more square miles of watershed and 705,527 more urban population than the Illinois.

The Mississippi river has 263,454 square miles more watershed and 834,340 more urban population than the Illinois, exclusive of the Sanitary District of Chicago.

The relation of square miles of watershed to population of the three rivers is as follows:

Missouri, 2 1-10 population to 1 sq. mi.

Mississippi river, 4 2-10 population to 1 sq. mi.

Illinois river, 16 7-10 population to 1 sq. mi.

Mississippi, above St. Louis, including Missouri and the natural Illinois, 3 2-10 population to 1 sq. mi.

The Mississippi, above St. Louis, including the Mo., Ill. and the Sanitary District of Chicago, 5 6-10 population to 1 sq. mi.

The Ill., including the Sanitary District of Chicago, 103.3 population to 1 sq. mi.

Where the population of the Sanitary District of Chicago is used in the foregoing determinations, it is assumed to be, in

full figures, 2,000,000 inhabitants, nearly all of whom reside in the city of Chicago.

By the addition of the population of the district to the watershed of the Illinois river, its population per square mile on the 17th day of January, 1900, was increased 520 per cent., or, differently expressed, is greater by 5.2 times the population residing upon its natural watershed. The opening of the canal at Chicago may also be said to have increased the population of the Illinois drainage basin from 385,305 to 2,385,305, or its original and natural population has become more than multiplied by six.

By the addition of the Sanitary District of Chicago to the Mississippi river watershed above St. Louis, including the Missouri and Illinois, the urban population sewering into the Mississippi has become increased by 75 per cent., or from 2,695,782 to 4,695,782, so that since the opening of the canal the water at St. Louis has in its flow received an increase of sewage polluting material to the extent of 75 per cent. over conditions existing prior to January 17, 1900.

The Missouri river from its source to the Mississippi
16 travels a distance of over 2,000 miles; the Mississippi from its source to St. Louis travels more than 900 miles, while the water from Chicago passes through the canal of the Sanitary District of Chicago into the Des Plaines river, and thence into and down the Illinois and Mississippi to St. Louis, a distance of 355 miles.

The character of the soil and territory traversed and drained by the respective rivers from a geographical, historical and geological standpoint is well known. All are known as western rivers, acting as drainage basins for the purpose of carrying off the sewage waste and filth of the people residing upon their respective watersheds.

Chicago is a large and populous city of about 2,000,000, and is rapidly growing beyond that number. It is an important manufacturing and trade center for the northern and northwestern territory of the United States. It contains many industrial enterprises and is one of the largest, in fact the most important live stock markets of the world; being noted for its extensive slaughterhouses and dressed beef and meat manufacturing establishments.

The Chicago river, and in fact all of the rivers that empty into the lake along the southern and western portions of Lake Michigan, you may say, have been formed as the water receded, so that they run parallel with the lake. They have been shut out from the lake as the waters receded, by ridges of sand and drift, which left them running parallel with the lake. There are no rivers reaching back into the country and discharging directly into the lake in the ordinary form of drainage. The rivers are all parallel, with occasional points where they break through the obstruction into the lake, and hence they are of minor importance, only covering a few square miles of drainage territory. The Chicago river proper is short, originally not over a mile long from the lake back to the confluence of the two forks, one leading from the south and one from the north; the southern fork called the south branch, and the northern fork called the north branch. The northern branch really drains the most territory and from a district of higher elevation as its source, in the state of Wisconsin. The south branch at a distance of about five miles from the lake, as it originally existed, has two branches, one known as the west fork, and the other as the south fork. The south fork drains a very limited territory, and can hardly be called a stream, except in flood periods. The west fork drains a small territory also, except as the flood waters of the Des Plaines river at a dis-

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tance of about nine or ten miles from the lake would break over and pass down it towards the lake. During such times it became much of a stream.

The Chicago river enters the lake at a point directly opposite the heart of the city, and with its branches and forks constitutes the natural outlet for the sewage, manufacturing and domestic waste of the city, except as to that portion sewering directly into the lake. For many years prior to January 17, 1900, it was not only a sluggish stream, but may be said to have been without a current to any perceptible extent. It was very foul, black in color and decidedly ill-smelling. Oftentimes it was covered with a black slime and was subjected to considerable agitation, due to the gases arising from the putrescent matter contained in the water.

Chicago lies very low. The elevation of the grounds within the city is from the lake level to a height of about twenty-five feet above the lake level, a very large portion of the city lying but a few feet above the lake level, so that its plan of sewage disposal has been to fill the streets and raise the grade above the original surface of the ground. In portions of the city, sewage districts have been laid out and the sewers so constructed below the lake level as to necessitate the pumping of the sewage at the sewer outlets. In other words, the sewage is pumped back to the lake level.

The original character of the soil on which Chicago is situated is reasonably firm, the greater portion being clay, originally overlaid with prairie soil. There is no gravel in the surface of the loamy soil; stone, however, is found underlying the clay. Some portions of the city, and the territory traversed by the drainage canal, cobblestone and a gravel material to a greater or less extent is found. In other places, a great mass of boulders cemented with clay exists.

The flat topographical condition of the land upon which
18 Chicago is situated rendered it impossible for the Chicago river to convey the sewage of the city a sufficient distance to remove its ill-effect upon the health and the convenience of the city. Frequent attempts have been made to open the Chicago river to a greater depth, extending its forks and branches, but all these endeavors have proven unsuccessful. No effort, however, has been made to treat the sewage in a systematic way so as to relieve it of its harmful substance before discharging it into Lake Michigan.

It will be observed that Lake Michigan is the natural basin for the sewage disposal of the city of Chicago. Yet, the facilities naturally provided for the city have become inadequate unless artificial means be resorted to. First, in either diverting the sewage to another watershed or by putting it through some course of treatment. At an early day the Illinois and Michigan Canal was constructed by the defendant state from the Calumet river, some distance south of the Chicago river, to the Des Plaines at Joliet and the Illinois river at Peru. Chicago was then a small city and no thought or attempt was made to transport the sewage of the city through this small artificial channel about six feet in depth and sixty feet in width. In fact, the city was too far removed from it and the sewage disposal system had been devised and started so as to force it into the lake, the natural basin of the watershed. The Illinois and Michigan Canal was constructed and used for navigation purposes. It remained in this condition from 1850 to 1871, when the flow became so low that navigation was impeded. The stock yards had been established south of the city on the south fork of the south branch of the Chicago river and north of Calumet river. The population of the city did not at that time extend into this district to any considerable extent. The South Fork at this

point was a very sluggish stream; in fact, it consisted of practically an artificial slip constructed and devised to carry away the washings from the stock pens and yards. It soon assumed a stagnant condition and so remained, having no effect upon the main body of the Chicago river and consequently poorly discharged the purpose of its preservation. Pumping works were established at Bridgeport for the purpose of lifting the 19 contents of the South Forth at the stock yards into the canal. Since then, during navigation seasons, about 10,000 cubic feet per minute has been discharged from the South Fork into this canal. The effect of the discharge was to cause the canal to assume a sluggish, foul, stagnant, septic condition, calculated to destroy the few pathogenic bacteria that found their way into it. The sewage discharged into this canal at Bridgeport has always been largely from the stock yards, and therefore not of the dangerous sort that comes from the heart of the great city. It was deposited into the canal in its raw state, free from dilution, and therefore possessing all the elements and characteristics of a septic tank, aiding, assisting, advancing and inducing a high stage of putrefaction, chemical reduction and bacterial destruction. After having remained in the river for an indefinite period it was discharged into the canal (a septic tank, so to speak), where it again remained for an indefinite time. During the winter months, when septic operation was less active, the pumps were closed. The filth and washings from the stock yards during the winter months either remained in the south fork of the river or were at times of heavy rainfalls and floods forced into the lake.

The small amount of matter conveyed through the Illinois and Michigan Canal is manifest from the fact that no observable effect was produced or had upon the quiescent and putrescent condition of the Chicago river. However, had this small amount

of polluting material been discharged through a canal and down a stream diluted with Lake Michigan water at the rate of 1,250,000 gallons per minute, the preservative influence upon the pathogenic substances contained in it might, and perhaps would, have become troublesome to people residing upon the stream at points below the initial discharge, and produced sickness and death among those using and drinking of the water.

The Des Plaines river is a small stream having its source in the State of Wisconsin, passing down through the northern portion of Illinois at a distance of about ten or twenty miles from Lake Michigan until it reaches Joliet, near where, in connection with the Kankakee, coming from Northern Indiana, the Illinois is formed. During a great portion of the dry seasons of the year, the Des Plaines is small and has practically no current whatever. During flood times, the water spreads over the territory near its mouth and runs into the Chicago river, driving sediment and infectious material from the Chicago river far out into Lake Michigan. Since the opening of the drainage canal, however, this condition has occurred but once.

The canal of the Sanitary District of Chicago was constructed by authority from the defendant state for the purpose of relieving the serious conditions which confronted the city of Chicago with reference to its water supply. The conditions affecting the drinking water of that city had become steadily worse from the days it became a city, and conditions were such that the public generally became much concerned and determined to devise some means by which the city could be relieved. This resulted in the organization of the corporation known as "The Sanitary District of Chicago."

The channel was then constructed from the southern branch of the Chicago river to the Des Plaines river, a short distance

above Joliet. It follows the general location of the old Illinois and Michigan Canal from Chicago to Lockport, and traverses the territory partly tributary to Lake Michigan and partly tributary to the Mississippi river, connecting with the Chicago river at Robey street in the city of Chicago, it runs southwestwardly, crossing the divide between Lake Michigan and the Mississippi river watersheds near what is termed the summit range line; an imaginary line dividing or separating the watershed of Lake Michigan from that of the Mississippi.

The first seven or eight miles of the channel passes through clay formation readily dredged. It is 110 feet wide on the bottom, with slopes one foot vertical to one foot horizontal, giving a surface width of 198 feet and a minimum depth of water 22 feet. At the end of this stretch of channel, a glacial formation is passed through. The full size of the channel through this glacial portion is 202 feet wide on the bottom, with sides slope of two feet horizontal to one foot vertical, resulting in a channel of 290 feet wide on the surface, with a minimum depth of 22 feet. Seven miles of the distance consists of a cut through solid rock, the sides being cut practically vertical. The
21 uniform width of the channel throughout this distance is 162 feet, with a depth of 22 feet.

The controlling works are located at Lockport and consists of seven lifting gates and one bear trap dam. Each gate has an opening of 32 feet and is worked and counterbalanced by winces so constructed that two men can raise and lower them under pressure, although the gates themselves weigh 62,000 pounds. It was necessary to construct this dam or controlling works in order to be able to, at all times, control the volume of water passing through the channel.

The Chicago river had been discharging the sewage of Chicago into Lake Michigan for a number of years. This dis-

charge polluted and infected the waters of Lake Michigan for a distance of several miles, the intakes of the Chicago waterworks being located out in the lake at a distance of from two to six miles from the shore. It was deemed more advisable by defendant to dispose of the sewage of the city through an artificial channel into the Mississippi river watershed than undertake the expense of extending the intakes of the waterworks system into the lake sufficient distances to be free of the contamination of the city at all times of the year. This is a significant fact when it is considered along with the proposition that Lake Michigan is practically a quiescent body of water. It is also the more deeply significant, as applicable to this litigation, when it is remembered that no concern whatever was given to the unfavorable injurious and damaging effect upon complainant's people and property. This inhuman conduct is intensely aggravated by defendant's knowledge that by the use of proper modern appliances for a comparatively inexpensive treatment of sewage, the injurious and infectious substances and organisms could have been successfully removed from the sewage of the district before being discharged into the water supply of the people residing upon an adjoining watershed.

Commencing on the Illinois river at Joliet, the following tributaries enter into it between that point and its mouth at Grafton: Des Plaines, DuPage, Kankakee, Fox, Vermillion, Mackinaw, Spoon, Sangamon, Crooked Creek, Macoupin
22 Creek, McKee's Creek. All of these tributaries are small, having comparatively small drainage areas.

Passing down the Illinois river from Joliet, there is a rapid fall in the channel from Dam No. 1 to the head of Lake Joliet, which is three and one-half miles southwestwardly. The fall in this distance is 21 feet. Lake Joliet, so called, is a widening of the stream to probably one-half mile, with something near five

miles in length. For a distance of about one mile from the mouth of what is called Lake Joliet, the fall is nearly ten feet. From this point the fall is gradual until the Marseilles dam is reached. The effect of the Marseilles dam upon the waters of the river prior to the opening of the channel was apparent for about 20 miles, the water being backed above Marseilles that distance. The fall at the dam is 12 feet. At Ottawa, about 8 miles from Marseilles, Fox river enters and the fall becomes gradual from this point to Peru at the head of the backwater from the dam at Henry, 29 miles below. The next dam below Henry is what is known as Copperas Creek, a distance of 59 miles. Between Copperas Creek dam and Henry dam the river forms what is known as Lake Peoria, a larger body of water, varying in width on an average of a mile and three-quarters to eight and ten miles in length; it is simply an enlargement of the river. LaGrange dam is 58 miles below Copperas Creek, while Campsville dam is 48 miles below LaGrange. Of these dams, the latter two were constructed by the United States Government in aid of navigation. The others were built by the state of Illinois.

Prior to the opening of the drainage canal, these dams caused the water to remain in practically a quiescent state during the greater part of the year, so much so that a green algae formation was observed during the summer months on the surface of the river. This formation constituted evidence of the destruction of the nitrogenous matter contained in the water, and of the process of self-purification constantly taking place, it being agreed by all the witnesses who testified in the case that water in a quiescent condition would more readily purify itself of its polluting material than when existing in a swift, running stream. The fishermen who lived on the Illinois river tes-
23 tified that during the greater portion of the year there was no perceivable current; that a chunk thrown in the water

would remain where deposited unless driven by the wind. This was the condition of the river both above and below the respective dams prior to January 17, 1900. Subsequent to the date of the opening of the drainage canal, there has been a continuous current from the source of the river to its mouth at Grafton. The dams have no consequential retarding effect upon the current. The green algae scum has disappeared, although it is a known fact that there remains in the water more of the constituent elements which form or produce the algae if a quiescent state could be obtained. In fact, more of the polluting and infectious material is now contained in the water than prior to the opening of the drainge canal; thus showing an extensive prolongation of the life of disease producing organisms under conditions now existing as compared to conditions prior to 1900.

For the purpose of this case, velocity observations on the water of the Illinois river from Chicago to Illinois were made by Professor Vanornum of Washington University, St. Louis, on the part of the complainant, and by Mr. Randolph, engineer in charge for the Sanitary District of Chicago, on the part of the defendants. Prof. Vanornum's observations were made during the spring season, while those of Mr. Randolph were conducted during the summer and autumn season. Mr. Vanornum's observations disclose that the water passed from the Chicago river at Chicago to the intake tower of the St. Louis waterworks at the Chain of Rocks in 9 days and three minutes, while Mr. Randolph's determinations show a time limit of a few minutes less than 15 days. The minimum flow of the river may be designated as about 8 days and the maximum flow at 18 days, with a mean velocity from Chicago to St. Louis of probably 10, at any rate not more than 12 days.

In passing judgment upon the sanitary condition of a water supply, the science of chemistry has long occupied an important position, while the science of bacteriology has also for some

years claimed an important position in this connection. Chemists have determined, in a general way, that the chemical conditions of a polluted water may by long experience be char-
24 acterized as follows: First, high free ammonia, high nitrites, high chlorine indicate sewage pollution. The foregoing is, of course, conditioned upon the hypothesis that the watershed of the stream examined is polluted and that there are no salt bodies of importance traversed or drained by the river. Second, high free ammonia, high nitrites and high chlorine with low nitrates indicate sewage pollution in its earlier stages. Third, high free ammonia and low nitrites with high chlorine indicate vegetable pollution with salt bodies located upon the watershed of the river. Fourth, low free ammonia, low nitrites and high chlorine and high nitrates indicate that the water examined may have been sewage polluted, but has remained in a quiescent condition a sufficient length of time and under such favorable circumstances as to largely reduce the organic matter therein contained and to some extent free it from its former polluting substance. It, however, does not necessarily indicate that disease producing organisms or pathogenic bacteria have disappeared.

According to the science of bacteriology, it is practically impossible to discover in a contaminated water the disease producing organisms; so small are the organisms and so delicate the test to be made. It has, however, been observed that where large quantities of bacilla coli communis have been found, it is a conclusive indication that the water is sewage polluted and, therefore, infected with disease producing organisms. The number of bacteria is important if the source of the polluting matter is known. However, bacteriologists, when applying the science to the sanitary observations of water, disregard largely the number of bacteria and depend mostly upon the character of the pathogenic organisms found.

Typhoid bacilli, the most dangerous perhaps of any of the water-borne diseases, has never been discovered in the waters of a running stream, save as to two or three reported instances, and from the present conditions of the science, their discovery is not a practical proposition. So it may be said that from the standpoint of bacteriology and chemistry, as applied to sanitary observations, there is no direct means of proving the absolute presence of pathogenic bacteria in water. A water supply may be chemically without fault and yet contain many living disease producing organisms. Or it may contain large quantities of organic nitrogenous substances so as to be condemned by the chemist, and yet contain no harmful substances; so likewise it may contain only a small number of bacteria, and be, therefore, not condemned by the bacteriologist, yet there frequently exists in such water sufficient pathogenic bacteria to produce an epidemic of typhoid among those who use it. It may be condemned by the bacteriologist as unfit for domestic use on account of the large number of bacteria, while as a matter of fact it is harmless and may be used with impunity.

The undisputed evidence, admitted by expert witnesses on behalf of defendants, show that in the chemical observations of a water supply the controlling factors depend upon the total amount of the organic nitrogenous matter contained in it. That this nitrogenous matter contains substances, some of which are decomposing in character, and others, under the test of bacterial chemistry, consist of living micro-organisms. No plan has yet been devised to determine the exact character of the organisms from a chemical standpoint. The intricate process employed by bacteriologists is such that the observer is permanently arrested in his attempt to separate the various living micro-organisms in the water to such an extent as to enable him to say of a certainty that no particular disease producing organisms exist in

it. Sufficient discoveries have been made, however, to enable an expert sanitarian to say with full confidence that each organism, like the human being, is endowed by nature with a distinct and separate existence or life. Some are frail and some exceedingly strong with highly vitalized powers. Some multiply in living natural waters and others do not. The general belief as to pathogenic bacteria is that they do not multiply or propagate in natural water, their ability to increase depending upon an introduction into the human system or a suitable media especially prepared. This may be stated as a general rule, and is followed by nearly every prominent and competent observer. It is not known that pathogenic bacteria feed upon anything while contained in living or polluted water, though some observers are inclined to that view. Not being dependent upon other forms of bacterial life for their sustenance, it is be-
26 lieved they live and spend their existence independent of their companions, having at least an equal chance with them till they have perished from a gradual loss of vitality, unless they sooner find their way into the system of some susceptible person where conditions are favorable for growth and multiplication. It is natural to expect them to possess a stronger vitality than the ordinary saprophytic bacteria, for with the latter when the field of their prey has become harvested their life task is completed. While the pathogenic bacteria, or the so-called parasite, being highly vitalized, as competent bacteriologists have observed, lives for a considerable time either in the presence or absence of nitrogenous compounds. Independent of other forms of bacterial life and largely capable of seeking agreeable conditions and surroundings (being motile) the conclusion comes as an unimpeachable certainty that as saprophytic influences are destroyed by dilution or by a removal of the nitrogenous compounds, the life of the parasite is thereby prolonged.

Laboratory experiments have been made as to the longevity of typhoid germs in various samples of water collected from various streams. Mr. Hiram F. Mills, for a long time chairman of the Board of Health of the State of Massachusetts, collected samples of water from the Merrimac river and deposited typhoid bacilli therein for the purpose of determining, if possible, both the longevity of the germs and their percentage of decrease from day today. It was discovered by him that they would live in a laboratory while contained in the waters taken from the Merrimac river for a period of 27 days, gradually reducing, of course, from the first day. From these observations made by him he prepared a table which represents the percentage of immortality of typhoid fever germs in the waters of the Merrimac river. Since this discovery, the table prepared by Mr. Mills has been used by scientists throughout the country in passing upon the sanitary conditions of water supplies and in determining the probability as to whether typhoid germs would pass from a given point where infectious material was being deposited in the stream to the intakes of the water supply.

Based upon this table, defendants introduced a chart showing the relative percentage of typhoid bacteria upon the
27 Illinois river watershed, including two millions of people from the city of Chicago, which would reach St. Louis within the life period of the germs. Basing the flow of the stream at 18 2-3 days from Chicago to St. Louis, it was found that the number of typhoid fever germs sufficiently vitalized to produce disease, which reach St. Louis within the time flow, would represent the total typhoid germs coming from the sewage of a city of 13,000 people situated immediately above the intakes at St. Louis on the Mississippi river. Based upon the mean flow of ten days, this determination results in the establishment of a city upon the Mississippi river immediately above the intakes

at the Chain of Rocks of 162,000 population. In other words, the effect of the sewage of Chicago upon the waters of the Mississippi river at the mouth of the Illinois has been such as if a large and popular city was established on the 17th day of January, 1900, upon the banks of the Mississippi river discharging its sewage into the waters of that river.

The chemical analysis discloses that the water in the Illinois river at Grafton contains more infectious material, material liable to contain infection, than it did prior to the opening of the drainage canal. It also discloses that the waters of the Mississippi river above Grafton and the Missouri river are freer from contaminating and infectious matter than the waters of the Illinois. This, of course, is but a natural condition. The sewage of two millions of people could not have the effect of improving conditions at any point on the Illinois river. Keeping in view the enormous number of typhoid fever germs reaching the Mississippi at St. Louis from Chicago, based upon the table of typhoid bacilli longevity of Hiram F. Mills, as introduced by defendants, it is but natural that St. Louis and complainant should suffer, and continue to suffer from the evil effect of the discharge of raw sewage into the canal at Chicago. The average number of deaths from typhoid fever among the 2,000,000 people living in Chicago for the last 12 years has been 776 per annum. Multiplied by 15 (the experience of the country showing that for every death there are at least 15 cases of the disease), there may be said to have been 11,640 cases per annum. The germs from this large number of patients
28 were deposited in the sewage of the city and by it conveyed and discharged into the waters of the Chicago river, thereby seriously infecting the water which, when conveyed into Lake Michigan, rendered the water of the lake unsuitable for domestic purposes.

Knowing that by the opening of the Drainage Canal of the Sanitary District of Chicago the infectious material from this large city would be discharged into the Illinois river and from thence into the Mississippi a short distance above the intake tower of the St. Louis waterworks, and knowing that it would have a harmful effect upon the water of the Mississippi from Grafton to the southern boundary line of the State; that people using the water for drinking and domestic purposes would suffer evil effects therefrom; that water-borne diseases would be conveyed to them thereby and the water rendered objectionable and injurious, this suit was instituted to prevent the discharge of the unpurified sewage of the city of Chicago and the Sanitary District of Chicago into the Illinois river through and by means of the canal.

The city of St. Louis had but recently, at an enormous expense, removed its intake to the Chain of Rocks so as to secure the best quality of water obtainable. Large reservoirs, as heretofore stated, were constructed at this point for the purpose of allowing the water to settle and sediment for a period of from 24 to 36 hours before being distributed to the people for use. The result of this improvement reduced the number of deaths from typhoid fever materially over former years. In fact, the number of deaths occurring from the disease for the years 1895 to 1899, inclusive, was as follows: 1895, 106; 1896, 106; 1897, 125; 1898, 95; 1899, 130. The ratio of deaths from typhoid during the period to each 100,000 population of the city being 19.6; a condition which compared favorably with the general run of the large cities througout the United States. Being much better than Chicago, Cleveland, Pittsburg, Philadelphia, Buffalo, Cincinnati, Louisville and other important cities. The ratio of deaths from the disease during these years was no greater in

St. Louis than in Boston, a city which boasts of its good water supply.

29 As contemplated by complainant as soon as the canal at Chicago was opened and the sewage of that city diverted to the Illinois and Mississippi rivers the death rate from typhoid in St. Louis started upward and has continued on the increase ever since. For the years 1900 to 1903, inclusive, the following number of such deaths occurred: 1900, 154 deaths; 1901, 181 deaths; 1902, 216 deaths, 1903, 281 deaths. The death rate from typhoid during this period per 100,000 population being 34.7. From the foregoing it will be observed that the typhoid mortality per 100,000 population in St. Louis for the years 1900, 1901, 1902 and 1903 increased 77.7 per cent over the typhoid mortality per 100,000 population in 1896-7-8 and 9. This enormous increase has occurred with no change in the manner of treating the water. The increase has been gradual, both in winter and summer seasons, with no relaxation in the least except that the percentage of increase has been greater in the winter seasons than during the summer months. All parts of the city where the public water supply has been used have alike suffered. No local epidemic has occurred; in fact, nothing has been observed, after a very searching investigation, that can in any way be charged with the cause of the increase save the discharge of the sewage of Chicago into the canal in question and hastening its flow to St. Louis by means of the Illinois river.

An attempt was made to show that this increase in typhoid in St. Louis since January, 1900, was due to the use of water from wells. The fact is that in those sanitary districts of the city having the greater number of wells there was less typhoid. For instance, District Number 2, with 1,073 wells, suffered in 1900, 14 deaths from typhoid; in 1901, 27 deaths, and in 1902, 21 deaths. In District Number 7, with 1,877 wells, there were

23 deaths from typhoid in 1900, 30 deaths for 1901 and 25 deaths for 1902; while District Number 3, with only 101 wells, had 28 deaths from typhoid in 1900, 30 for 1901 and 36 deaths for 1902.

An examination was then made of conditions that existed at St. Charles, situated on the Missouri river about 40 miles from St. Louis, and Alton, Ill., on the Mississippi river, about 30 miles from St. Louis. It was disclosed that in these cities there was no increase in typhoid since the opening of the drainage canal. The examination extended to all the principal cities upon the watersheds of the Mississippi, Missouri and Illinois rivers, where correct data could be obtained, and it was found that no apparent increase in deaths from typhoid had occurred upon the entire watershed of the Mississippi river above St. Louis, exclusive of the city of Chicago. Upon the Missouri river watershed, the typhoid mortality of the following cities for the years 1897 to 1902 was obtained: Lincoln, Omaha, Council Bluffs, St. Joseph and Kansas City, the cities of Jefferson City and St. Charles not being included for the reason that no mortality record existed prior to 1899. The total number of deaths per year occurring on this watershed, as shown by the mortality record of the above named cities, was as follows: 1897, 97 deaths; 1898, 118 deaths; 1899, 136 deaths; 1900, 108 deaths; 1901, 112 deaths; 1902, 109 deaths.

The Mississippi river watershed above the mouth of the Illinois was examined for the purpose of determining whether or not there had been an increase in typhoid in the respective years with the following results: 1897, 274 deaths; 1898, 252 deaths; 1899, 220 deaths; 1900, 256 deaths; 1901, 289 deaths; 1902, 202 deaths, the foregoing results being obtained from the mortality of the following cities on the above mentioned watershed: St. Paul, Minneapolis, Red Wing, Minnesota, Winona, LaCrosse, Dubuque, Clinton, Iowa; Rock Island, Moline, Daven-

port, Muscatine, Burlington, Keokuk, Quincy, Hannibal and Des Moines, the cities of Fort Madison, Iowa; and Louisiana, Missouri, being omitted for the reason that full statistics could not be obtained in reference to them.

Upon the Illinois river watershed, the following cities were examined for the purpose of determining the mortality record: Peoria, Bloomington, Ottawa, Decatur, Joliet, Elgin and Aurora, the cities of Springfield, Pekin and Havana being omitted for the reason that full reports could not be obtained. The totals for the respective years of these cities being as follows: 1897, 64 deaths; 1898, 66 deaths; 1899, 55 deaths; 1900, 107 deaths; 1901, 73 deaths; 1902, 70 deaths. The total results show the following number of cases occurring in the principal cities on the watershed of the Mississippi river above St. Louis for
31 1897 to 1902, inclusive, to be as follows: 1897, 435 deaths; 1898, 438 deaths; 1899, 411 deaths; 1900, 471 deaths, 1901, 474 deaths; 1902, 381 deaths, or an annual average for three years prior to the opening of the canal of 428 deaths and for the three years after the opening of the canal of 409 deaths.

With the great number of typhoid cases appearing annually in the city of Chicago, it is conclusive that the cause of the increase in St. Louis is due to discharge of the sewage of Chicago through the artificial canal constructed by the defendant, The Sanitary District of Chicago.

The effect of the canal upon typhoid conditions in the city of St. Louis is more apparent during the winter than the summer seasons. A comparison of conditions during the winter months of 1896-7-8 and 9 with the winter months of 1900-1-2 and 3, based upon the number of typhoid deaths in St. Louis per one hundred thousand population, shows an increase of 94.8 per cent, while during the summer months, an increase of 65.7 per cent. The increase in the total number of deaths in the city

from typhoid, regardless of population, during 1900-1-2 and 3 as compared with the period of 1896 to 1899, inclusive, was 118.2 per cent during the winter months and 84 per cent during the summer months, while, as hereinbefore stated, the total increase per one hundred thousand population in typhoid fever deaths during the period prior to the opening of the canal as compared with the same length of time after the opening of the canal was 77.7 per cent; the total increase, regardless of population, being 95 per cent.

The evidence discloses the germs of tetanus (lock jaw) and anthrax to have been discovered in the waters of the Illinois river since the opening of the canal at Chicago.

It is but natural to believe that with a stream velocity of from 8 to 18 days from Chicago to St. Louis considerable infectious material finds its way to St. Louis. While it is true large numbers of the disease producing organisms perish on the journey, yet experience of the people at St. Louis shows that a considerable number pass through unharmed. This is in keeping with the declaration of Prof. Mason, one of defendants' witnesses, to the effect that "undoubtedly some of the more
32 persistent organisms retain their vitality throughout the journey." The fact that there has been a greater increase in the death rate from typhoid at St. Louis during the winter months is not surprising, for Chicago is noted for its winter typhoid, and it is admitted that the germs of typhoid live longer and consequently travel farther in cool weather than in warm.

The enormous increase in deaths and cases of typhoid in St. Louis caused by the discharge of sewage from the city of Chicago into the Mississippi has been a source of financial loss to complainant. It has been truthfully said that "The average city of 100,000 population wastes perhaps half a million dollars per year on the luxury of having it." Not only is it a long,

tedious and grave illness, often leaving life-long disabilities in its wake, but it is also one of the most expensive of ailments.

Counting each death in the city of St. Louis caused by the sewage from Chicago as having a value of $5,000, the loss to complainant is no small matter. While if we take into consideration the cost and expense of treating and nursing those cases wherein a recovery is had, together with the loss of labor while ill, the loss to the community reaches a total of many hundred thousand dollars per annum. This is the financial loss. The sorrows of death, pains of sickness and mental distress cannot, from the standpoint of humanity, be measured in dollars and cents.

Prior to the opening of the drainage canal, the passage of the sewage infected material from Chicago river into Lake Michigan created typhoid conditions in Chicago bordering upon an epidemic at almost all seasons of the year. This occurred regardless of the fact that the city continually from year to year extended its water intakes a greater distance towards the middle of the lake, some of the cribs being located six miles from the lake-shore. Observing that the water of the lake is in practically a quiescent condition during a greater portion of the time, and that typhoid germs pass from the river a distance of several miles to the intake in sufficient time to remain virulent and vitalized after passing into the water supply, and thence distributed to the citizens, is not an unreasonable disclosure to find them passing down the rivers to St. Louis; the distance
33 traversed being governed largely by the longevity of the germ and the velocity of the stream. Typhoid organisms are shown to live in laboratory observations for a period varying from thirty to ninety days in living water. It is true the saprophytic influences upon the parasites, or disease producing organisms, contained in sewage is considerable, yet scientists

have observed the presence of typhoid fever germs in raw sewage for a period of from seven to nine days. The dilution of sewage with water has a tendency to largely destroy the saprophytic influences in that it removes the parasites a greater distance from evil influences and effect, thus encouraging their life. By the addition of 250,000 cubic feet, or 1,625,000 gallons per minute, of water passing from Lake Michigan into the canal, the effect produced upon the disease producing organisms coming from the sewers of Chicago is such as to extensively prolong their life. By this means they are enabled to travel a greater distance down the Illinois and Mississippi rivers than under conditions which existed in the Chicago river prior to the opening of the canal. Before the canal was opened, the sewage of Chicago was discharged into the river, which was then, practically speaking, a large septic tank. The natural outlet of this river is Lake Michigan. The contents of the river remained in a quiescent condition a greater part of the year and were seldom discharged into the lake except during high rainfall periods and freshets. When these took place, the river was gulched into the lake and this produced an evil effect upon the health of the people residing in the city. While the river remained in this stagnant, putrefied condition, its contents were broken up by aerobic influences and finally by anaerobic action became largely exempt from infectious organisms, yet, the observation of scientists upon conditions at Chicago were such as to lead them to believe that sufficient pathogenic bacteria remained in the putrefying mass in the river to create unfavorable conditions in the water supply of Chicago and to cause an abnormal mortality death rate from typhoid fever in that city.

Under present conditions, the germs of disease are deposited into the channel at Chicago, and from thence pass down
34 the Des Plains and Illinois rivers and the Mississippi to and below St. Louis uninterrupted and under atmospheric

and physical surroundings such as tend to prolong their life rather than retard it.

The fact that disease producing organisms pass from Chicago to St. Louis is conclusively demonstrated when reference is had to a long list of typhoid epidemics that have occurred in Europe and this country in recent years. In nearly every instance, the epidemic has been caused by the infection of the water supply at some point above the intake, the distance in each instance varying to a considerable extent.

At Luzon, Switzerland, in 1872, the epidemic, after investigation, was found to be caused by the infection of a brook which passed through the mountain for a distance of one mile, the infection evidently occurring before the water had started through the mountain, its natural filtration plant. So perfect was the natural filter provided for by the mountain, that large quantities of flour were deposited in the stream above, but no evidence of starchy formation or of the flour could be detected at the brook. A number of barrels of salt were deposited in the water immediately before it started through the mountain, the water in the brook being examined a short time afterwards, was found to contain chlorine, or saline substances, demonstrating that the water in the brook came from the infected source. While the filtration was sufficient to protect it against the passage of flour or its entrance into the brook, it was not sufficient to prevent the passage of typhoid fever germs.

Plymouth, Massachusetts, is another instance of an epidemic due to the infectious condition of the water supply. Lowell, Massachusetts; Windsor, Vermont; Pittsburg, Pennsylvania; New Haven, Connecticut, and other points suffered severe epidemics from the same cause, while at Detroit, Michigan, in 1892, a severe epidemic of typhoid fever occurred, which, after careful and continued observations, was traced to dredging by the

government from deposits at the mouth of Black river, a distance of 57 miles above Detroit, with St. Clair lake lying between the two points. The time required for the water to flow from Port Huron, at the mouth of Black river, to Detroit, after a careful observation by Mr. Gardner S. Williams, was found to be about thirteen days.

Washington City, D. C., has suffered enormous loss from typhoid fever. Only a few years ago an epidemic broke out in the city. So prevalent was the disease that it became alarming. Investigation of the cause made it clear that the water of the city was infected by the discharge of typhoid laden sewage in the Cumberland river, 150 miles above the city.

At Pittsburg, Pa., in 1898, the typhoid germs are known to have traveled in the water of the river from Oil City, a distance of 110 miles, in sufficient numbers to cause an epidemic of the disease.

At Buffalo, N. Y., the water supply is infected, although it is drawn from what might be termed the mouth of Lake Erie, having passed down one of the most favorable streams in the world from the standpoint of dilution, aeration, oxidation and similar processes.

Niagara river is an enormously large stream, Niagara Falls filters its water, but so imperfect is the filtration process that typhoid conditions are always high in this city.

It is a well known fact that at Covington, Kentucky, and New Albany, Indiana, the water for domestic purposes is conveyed into large reservoirs and there contained for a period of thirty days before being distributed to the people for use; and yet, after its long wait in the supply basins, sufficient typhoid fever germs survive to produce an enormous typhoid mortality in the respective cities. With these facts before us, it is demonstrated beyond all human probability that the disease producing

germs will and do pass from Chicago to St. Louis under present conditions.

Prior to the opening of the Chicago drainage canal, the five dams, which have been constructed across the Illinois river, acted as barriers to the progress of the water and created large sedimentation basins by which a great portion of the bacterial contents of the water in the river passed to the bed and there remained until perished or until some freshet or increased volume of water had carried them further down stream. In other words, the process of sedimentation, as well as the
36 process of septic operation as hereinbefore mentioned, was more proficient prior to the opening of the canal than subsequent thereto, the dams of the river now being entirely insufficient to retard the water to any considerable extent as it passes down stream.

Living organisms contained in the waters of Lake Michigan are natural habitants thereof, but not found in the waters of the Missouri, Upper Mississippi or the tributaries of the Illinois, were discovered by the analysts in the waters of the canal, the Illinois and the Mississippi river below Grafton, thus showing conclusively the discharge of living organisms from Lake Michigan to St. Louis. One hundred and seven barrels of bacilli prodigiosus containing one thousand million bacteria per cubic centimeter were deposited in the drainage canal at Chicago. Within the ordinary time flow from Chicago to Grafton to St. Louis, bacilli prodigiosus were discovered in samples of water collected from the Illinois river at Grafton and the Mississippi river at the Chain of Rocks. This is important when considered along with the well known proposition that this particular bacilli is not a natural habitant of any of the waters of this country. It is not found in the waters of Lake Michigan, the Illinois, Missouri or Mississippi rivers or their tributaries. Again show-

ing conclusively that living organisms will and do pass from the great lake to the Mississippi by means of the artificial waterway. It is also a conceded fact that the life of the bacilli prodigiosus is similar in point of duration to that of the bacilli typhosus, or typhoid fever germs.

In addition to the constantly increasing infection of the river from the sewers of Chicago, it is an admitted fact that the increased volume and flow of the water caused by the discharge of 250,000 cu. ft. per minute through the canal quickens the passages of disease producing organisms from Havana, Pekin, Peoria, LaSalle and Joliet to the Mississippi river and to St. Louis.

It is necessary to take into consideration the combined urban population residing upon the watershed of a river in order to express an opinion as to the sanitary condition of the water of the river at any given point.

The population residing upon the natural watershed of the
37 Illinois river brands it as more heavily infected than either the Mississippi or Missouri river. Physical and atmospherical conditions also must not be overlooked.

The population upon the watershed of the Mississippi river has already burdened it with an immense sewage disposal. As population increases, the burden will become the more burdensome to those municipalities which are compelled to use the water of the river for domestic purposes. The time is not far distant when much trouble will arise in this connection, making it impossible to secure suitable water without very expensive treatment and improvement plants. The discharge of the sewage from Chicago into the drainage basin of the Mississippi has not only hastened that condition, but if not restrained, will compel St. Louis to spend many million dollars in the construction of a filter plant in order to force its typhoid mortality back

to conditions similar to 1896-1897-1898 and 1899. The danger and damage to complainant, the menace to its welfare, the loss of its reputation as a city of comparatively low typhoid mortality and the impediment to its financial and industrial growth caused by the injury sustained and the constantly increasing embarrassing conditions manifestly convict defendants of the injuries complained of, and unquestionably warrant the decree so earnestly requested.

Much might be said of what may be expected in the future, as shown by the evidence in the case, if present conditions are permitted to become permanent. Ere long we may depend on Chicago having a population of more than 5,000,000. That city will then, so to speak, be brought nearer to St. Louis, in so far as its contaminating effect upon the water supply is concerned. The volume of the water passing through the canal will be necessarily increased, thus hastening the flow down the river. We need not, however, look to future developments for grounds of relief, the existing conditions are amply sufficient. We have, in the foregoing, stated the facts as they exist in the record, without embellishment or color. Every statement made is fully supported by facts known and shown to exist.

QUALIFICATION OF WITNESSES.

38

A number of experienced witnesses testified in behalf of complainant, fully substantiating complainant's position and conclusively showing great injury and damage to the State of Missouri by the operation of the canal of the Sanitary District of Chicago. They qualified as competent witnesses as follows:

DR. AMAND NICHOLAS RAVOLD testified on behalf of complainant and qualified as an expert Bacteriologist, as follows:

Dr. Ravold lives at No. 2806 Morgan street, St. Louis, Missouri, and has been a practicing physician in the city of St. Louis since 1881. Since 1885 he has been a professor of Bacteriology. In addition to the general work as a scientist, he was in 1886 connected with the Shaw School of Botany at St. Louis as Assistant to Professor William Trelease at Washington University, a University of national reputation and standing. In 1887 he became a lecturer on Bacteriology in the Medical Department of Washington University, which was then known as the St. Louis Medical College. Later he was made Professor of Bacteriology in the Medical Department of Washington University, and continued in that position until 1902, when he resigned to go abroad. While he was connected with the St. Louis Medical College, as above stated, it was consolidated with and became a part of the Washington University, and known as the Medical Department of Washington University. Later, and during the time he was connected with the school, the Missouri Medical College was consolidated with the St. Louis Medical College, both now belonging to the Washington University and passing under the name

of the Medical Department of Washington University. The Missouri Medical College was founded more than fifty years ago and the St. Louis Medical College was founded many years ago, both of which institutions were, at the time of their consolidation with Washington University, well known with national and state reputations, recognized throughout the world as first class institutions, giving to their students the highest possible
39 education upon subjects affecting the medical science. In the commencement of his work with these institutions, Dr. Ravold was placed in charge of the technical training of bacteriologists, and during the entire period of his professional career, both as a practicing physician, as a scientist and as an instructor, he employed and followed the best known practical means of making bacteriological determinations. As a general rule, on experiments made in this case, he adopted and followed the methods laid down by the Bacteriological Department of the American Public Health Association, of which he was and now is a member. During all the time of his employment with the institution above mentioned, he was engaged in teaching bacteriology from the latter part of September until May of each year.

In addition to the above work, Dr. Ravold was in 1894 employed by the City Health Department of the city government of St. Louis to aid in the bacteriological work of the Health Department. His title was that of Consulting Bacteriologist. During this time he carried out experiments of the Department on Diseases known as tuberculosis, diphtheria, typhoid, blood poisoning and various other diseases that came before the public for consideration, and to considerable extent investigated the subject of anti-toxin for diphtheria. During the time he was employed by the city government he continued his connection with Washington University.

(Printed testimony, Volume 1, pages 1 to 8.)

As positive proof of Dr. Ravold's qualifications to perform the duties devolved upon him in this investigation, a more complete understanding as to his fitness can be obtained by reading the first fifty-eight (58) pages of the printed testimony, which shows clearly his perfect acquaintance with the science of bacteriology in various forms and the kinds of bacteria, together with the name of the discoverer of each and the date of the discovery, as well as of the many peculiarities and characteristics of the respective bacteria.

In addition to his bacteriological work, Dr. Ravold lectured for a number of years upon Pathology and Hygiene in the Medical Department of Washington University of St. Louis, and by reason thereof, and of his careful study of the subject, he is well acquainted with the sanitary conditions required of a water for domestic use, and is acquainted with the history of the examination of the sanitary conditions and surroundings of the water supplies of the different cities of the world as connected with the epidemic of typhoid and cholera.

(Printed record, volume 1, pages 462-463.)

DR. WILLIAM C. TEICHMANN, at page 640 of the printed record, volume 1, qualified as a professional chemist, as follows:

Dr. Teichmann lives at No. 3624 Shaw Avenue, St. Louis, Missouri, and at the time of testifying occupied the office of City Chemist of the city of St. Louis, having occupied that position since April, 1893. He was, therefore, well acquainted with the chemical and bacteriological investigations of the waters of the Mississippi river, the Missouri river, the Illinois and Des Plaines river, and the Chicago Drainage Canal, begun by authority of the city of St. Louis in 1899, continuing throughout 1900, 1901, and 1902. During all of this time he had charge of

the Chemical Department of the investigation and organized the system for the collection of samples of water for the chemical analysis. He was ordered by the Health Commissioner of St. Louis to take samples of water for examination from the mouth of the Illinois river and the Illinois river itself, as well as from a point above the mouth of the Illinois river, and also between the mouth of the Illinois and the Chain of Rocks.

Dr. Teichmann was educated originally at Washington University, St. Louis, Missouri. He left Washington University in 1875 and in the fall of that year entered the Polytechnic College of Brunswich, Germany, where he studied the science of Chemistry from 1875 until the summer of 1879. In the fall of '79 he entered the University of Berlin at Berlin, Germany, where he studied chemistry and a number of other corresponding branches like history and literature for general educational purposes until 1881. In Berlin he studied under Professor Ferdinand Tiemann, who at that time was considered one of the leading authorities on water analysis, and the author of the well known standard work on water analysis.

In 1881 Dr. Teichmann entered the University at Liepsic,
41 where he remained until the spring of 1882, when he entered the University of Munich in Germany, and graduated as a doctor of philosophy in chemistry and history in the year 1885, having practically ten years of education as a chemist—six years of which was strictly confined to the study of chemistry from a practical standpoint. While he attended the University of Berlin his work was for the greater part confined to the study of the analysis of water under Professor Tiemann. In 1885 Dr. Teichmann returned to this country, and in 1890 became private assistant to Professor Charles O. Curtman, Professor of Chemistry in the Missouri Medical College. In 1891 he became assistant instructor of Chemistry in the Missouri Medical

College, which position he retained until 1895, and during this time he assisted in quite a number of water analyses. In 1893 he was appointed City Chemist of St. Louis, and has occupied that office continuously since. As city chemist his duties were multifold, consisting of analytical work for the Health Department, which included a constant analysis of well water and of cistern water, the analysis of disinfectants used by the Health Department, all kinds of medicines and articles of food purchased by the city institutions and for the Police Department. Also various analyses were made by him for the School Department and the Board of Education. He also performed analytic work for the Water Department by making daily analysis of the city supply.

(Printed record, volume 1, pages 640 to 649, inclusive.)

By reading the foregoing pages of the record, Dr. Teichmann's qualification as an expert chemist, qualified to testify with reference to the sanitary condition of the water supply of the water of St. Louis and the effect of the sewerage of Chicago upon the Mississippi river, will appear unquestioned.

PROFESSOR EDWARD H. KEISER, qualified as a witness on behalf of complainant as a professional chemist, as follows:

Professor Keiser had been occupying the position of Professor of Chemistry in Washington University of St. Louis,
42 Missouri, since the fall of 1899, coming to this position from Bryn Mawr College near Philadelphia, Pennsylvania. He occupied the position of professor in the last named institution for fourteen (14) years prior to his employment with Washington University. For about two years before this he was connected with Johns Hopkins at Baltimore as an instructor in

chemistry, and for two years prior thereto was a Fellow in Chemistry in Johns Hopkins University.

In 1880 was graduated from Swarthmore College, Pennsylvania, taking the degree of Bachelor of Science, and in 1881 there was conferred upon him by that institution the degree of Master of Science; in 1884 he took the degree of Doctor of Philosophy in Johns Hopkins University of Baltimore, and in the summer of 1884 he studied in Germany at Freidburg, in Saxony, and in 1887 in Gottingen University, and in 1894 he studied at Heidelberg, Germany. All of the time being engaged in and pursuing a careful study of the Science of Chemistry.

In January, 1900, he was employed by the Water Commissioner of St. Louis and the city chemist of St. Louis to make certain examinations of the waters of the Mississippi, Missouri, Illinois and Des Plaines rivers and the Chicago Drainage Canal. During all his work Professor Keiser's attention was particularly called to the analysis of water, and the adaptability of water for domestic use.

(Printed record, volume 1, pages 968, 969, 970 and 971.)

J. L. VAN ORNUM, qualified as a witness on behalf of complainant.

Mr. Van Ornum is a resident of the city of St. Louis, a civil engineer by profession, and at the time of testifying was Professor of Civil Engineering in Washington University, having been engaged in this profession since graduating in 1888, at the University of Wisconsin. He had been connected with Washington University as Professor of Civil Engineering for four years prior to testifying, and still occupies that position. Before connecting himself with the above named university he was engaged in the practice of his profession in different parts of the country,

his work consisting of municipal and railway engineering
43 and work under the government on rivers and harbors. He spent two years in the service of the United States surveying the boundary line between this government and Mexico.

Mr. Van Ornum, during the month of March, 1903, determined by means of floats deposited in the water, the time required for water to flow from Lake Michigan to St. Louis. This work was done under the direct supervision and management of Mr. Van Ornum for the purposes of this case.

(Van Ornum's testimony, Vol. 2, pages 1732 to 1736, inclusive.)

GEORGE CHANDLER WHIPPLE, qualified as a witness on behalf of complainant, as follows:

Mr. Whipple is a resident of Brooklyn, New York. He is biologist and director of Mount Prospect Laboratory of the department of Water Supply, Gas and Electricity of the city of New York, having occupied that position since 1897. He was graduated from the Massachusetts Institute of Technology in 1889, taking a course of civil engineering. During the summer vacation previous to graduating he was Inspector of Tenement Houses in the city of Boston; after graduating he was employed for several months by the Superintendent of the Boston waterworks to perform certain experiments in the filtration of water through a sponge. In the fall of 1889 a biological laboratory was established by the Boston Water Department and Mr. Whipple was placed in charge of that work under the title of Biologist. His work in that laboratory consisted in the inspection of all the sources of water supply of the city of Boston, and in addition to the inspection of such sources, microscopical examinations of the waters were made. Those examinations consisted of, first, physical examinations; second, bacteriological examinations,

and, third, chemical analyses of the various sources of supply. In connection with this work he made a test of the sewage disposal system at South Framingham, located upon the watershed above Boston. Similar examinations were made of the sewage disposal system of Natick, Mass., and frequent tests of Pegan Brook, in Natick, Mass. Inspection trips were made which covered all the large water supplies of Massachusetts for the purpose of comparing the water of Boston with those of the 44 cities tested. Frequent trips were made to the Lawrence experimental station, constructed by the Massachusetts State Board of Health, the object being to observe experiments carried on there. For three years he had charge of an experimental filter plant carried on in connection with the Biological Laboratory of Boston, and during the eight years he was connected with this laboratory, numerous experiments were made in the growth of microscopic organisms, upon the temperature of large bodies of water, particularly in regard to the so-called stagnation phenomenon. He assisted in designing an instrument called the thermopome, for obtaining the temperature of water at the bottom of reservoirs. From 1893 to 1896 he had charge of the Biological Laboratory under the direction of the Waterworks of Lynn, Mass., where similar tests were made.

In 1896 four months were spent with Prof. Albert R. Leeds of Hoboken, New Jersey, where he assisted Prof. Leeds in studying the water of Brooklyn, New York, which at that time was affected with bad odors.

In 1897 he established a laboratory known as the Mount Prospect laboratory, in connection with the Brooklyn Water Department, having charge of its equipment and planning the work. The scope of this laboratory was extended after annexation of Brooklyn to the city of New York, and analyses of water made which included chemical, physical, microscopical and bacterio-

logical tests, covering the Borough of Queens, as well as the Borough of Brooklyn. In January, 1903, the scope of this laboratory was further extended and now covers the entire water supplies of the city of New York. In connection with this work he has had various occasions to visit all the watersheds, to keep close lookout as to the presence of typhoid fever in the city, and in general watch the sanitary condition of the water supply, having in this way investigated a number of local epidemics of typhoid fever.

Early in 1903 he was appointed one of a commission to study the future supply of water for New York City, the commission being known as the Commission on Additional Water Supply. All the sanitary investigations involved in that problem were placed in his hands. Under his direction a tem-
45 porary laboratory was established at Poughkeepsie, and another at Katonah. The commission, under the supervision of Mr. Whipple, is making a careful study of all the sources of water supply that are available to the city, which includes practically all waters of the eastern part of the State. A careful study is being made of all streams that drain into the Hudson river, as well as the Hudson river itself. In connection with his laboratory work he has recently made a test of the electrozone process of purifying water, and is preparing a design for a sand filter to filter 15,000,000 gallons of water per day on the Croton watershed. In addition to the foregoing, he is now making tests with a sand filter at Poughkeepsie, and carrying on experiments of sedimentation of water at Poughkeepsie, as well as studying the question of how far sea water runs up the Hudson river under different conditions.

In addition to the foregoing, Mr. Whipple has had considerable private experience as a sanitary expert, and during the last several years has examined waters from nearly every state east

of the Mississippi river, from Cuba, Egypt and India. He has carried on a series of examinations of samples of water from Little Falls, New York; Watertown, New York; Oswego, New York; Birmingham, Alabama; Red River, Louisiana, and the Delaware river at Trenton; from the Susquehanna at Binghampton, and the Wabash at Vincennes, Indiana, and elsewhere. He has also made a report on the electrolic manner of water purification for the United States War Department, and is consulting chemist for the Water Department of Binghampton, New York, where a mechanical filter has been constructed which filters water at the rate of six million gallons per day, Mr. Whipple having had the practical charge of the operation of this filter during the past year. He investigated an epidemic of typhoid fever at Waterville, Maine, which extended also to the towns of Fairfield, Winslow and Benton. He is employed as sanitary expert for the Kennebec water district, and has published sixty to seventy pamphlets relating to water and sanitary matters, and is the author of a book on the microscopy of drinking water, the title being "Microscopy of Drinking Water, by George Chandler Whipple," which was published by John Wiley & Sons, in 1899. Many experiments were made by him affecting the method of water analyses, as well as devising the so-called silica standard for the measurement of turbidity of water, which has been accepted by the United States Geographical Survey. He devised a scheme for tabulating odors which was accepted by the American Public Health Association.

Mr. Whipple is a member of the American Society of Civil Engineers, the American Chemical Society, the American Microscopical Society, the Society of American Bacteriologists, the American Public Health Association, of which he is Secretary of the laboratory section, and the Society of Chemical Industry.

He is also a member of the American Limnological Commission, and Fellow of the Royal Microscopical Society of London, and Secretary of the Committee on Standard Methods of Water Analyses of the American Public Health Association.

The foregoing qualifications are to be found in Vol. 2, pages 1903 to 1908, in the record.

WILLIAM THOMPSON SEDGWICK, qualified on behalf of the complainant, substantially as follows:

Professor Sedgwick resides at Boston, Mass. He was graduated at the Sheffield Scientific School at Yale, in 1877, and studied for the greater part of two years in the Yale Medical School, taught physiological chemistry at Yale for one year, and became fellow, assistant and associate of Johns Hopkins University, Baltimore. He went to Boston in 1883 and since that time has been assistant professor, associate professor and professor in the Massachusetts Institute of Technology of Boston. Prof. Sedgwick received the degree of Doctor of Philosophy at Johns Hopkins in 1881. He served as biologist for the State Board of Health from 1888 to 1891, and is a member of the American Academy of Arts and Sciences, Massachusetts Associations Boards of Health, New England Waterworks Association, Society of American Bacteriologists, American Society of Naturalists, American Public Health Association, Member of the Advisory Board of Hygiene, Laboratory of the United States, Public Health and Marine Hospital Service, Past President of the American Society of Naturalists and Society of
47 American Bacteriologists. He has been employed by various cities and towns as an expert on water supply or sewage disposal; especially at Burlington, Vermont; Pittsburg, Penn.; Lowell, Mass., and other places. He is the author of a text-book on Biology, a treatise on the Principles of Sani-

tary Science and Public Health, published in 1902, and has made numerous reports of investigations of epidemics of typhoid fever for the State Board of Health of Massachusetts, also a report on typhoid fever in Pittsburg in 1898. Prof. Sedgwick has published numerous papers on water supply, water purification and sewage purification, besides a paper on typhoid fever in Chicago in 1902, in connection with Allen Hazen, the well known sanitary engineer. He is a biologist, bacteriologist and epidemiologist.

(Sedgwick's testimony, Vo. 3, pages 2184 and 2185.)

GARDNER STEWART WILLIAMS, qualified as witness for complainant, as follows:

Mr. Williams lives at Ithica, New York, his present occupation being that of consulting water supply and hydraulic engineer, and Professor of Experimental Hydraulics in Cornell University, having been connected with Cornell University in the above capacity since 1898. He was educated in the high schools of the state of Michigan, and in the Engineering Department of the University of Michigan, taking the degree of Bachelor of Science and Civil Engineering in 1887; in 1889 the advanced degree of Civil Engineering was awarded him as a result of his experience and study in connection with water supply from a sanitary standpoint, and the diseases likely to be communicated by them, and investigations made upon the flow of water. The results of some of these investigations were presented to the American Society of Civil Engineers during the past two years, and he received the Normal medal awarded by that Society.

Mr. Williams began his experience as a water supply engineer in connection with the construction of waterworks at Bismarck, N. D. At that time he was also in charge of the con-

struction of waterworks in Greenville, Mich., and afterwards at Owosso, Mich. In 1893 he became civil engineer to the Board of Water Commissioners of the city of Detroit, in which
48 position he had the responsible charge of the design and construction of all engineering work that was done in connection with the plant of the city of Detroit, which was then supplying between 270,000 and 300,000 people with water, and had a distributing system of between 400 and 500 miles. He retained this position until the fall of 1898. During those years he was engaged as consulting engineer in connection with numerous other plants, prepared plans and specifications and had supervision of construction work at several other places, and since that time has prepared plans for, and superintended the construction of extensive additions to the waterworks plant at Ithica, New York and is now consulting engineer of the Ithica Waterworks Company. During the last ten years Mr. Williams has made the study of water supplies one of his principal occupations. The hydraulic laboratory of Cornell University has been under his direction and charge since the fall of 1898, and this laboratory is by far the most extensive hydraulic experimental station in the world. During the time he has had charge of that laboratory, expensive experiments have been carried on as to the flow of water in open channels and over dams. Part of those experiments have been made under and for the United States Board of Managers on Deep Waterways, and in connection with the Croton supply and in part in connection with the New York State Survey. At the time of testifying, Mr. Williams was engaged in extensive experiments for the United States Survey. In addition to the foregoing he has made a number of important investigations and experiments in the laboratory of Cornell. He has also been engaged in investigating the flow of water at Holyoke, Mass., Sault Ste.

Marie, Mich., and the discharge of the Ste. Marie river at Sault Ste. Marie, Mich., and during his work at Detroit in connection with the Detroit Waterworks he had occasion to make an extensive series of investigations on the flow of the American channel of the Detroit river, and on numerous occasions has investigated the problem of water flow. As a water supply engineer he has been closely identified with and interested in such diseases as are influenced by the quality of water used, and has made investigations of typhoid epidemics in Detroit, Sagi-
49 naw and Charlevoix, Mich.; Ithica, New York, and other places, and has extensively studied all information published in regard to epidemics of water-borne diseases, both in this country and abroad, and to a considerable extent has made epidemiology a branch of his study in connection with water supply. (Record, Vol. 3, pages 2418 to 2420.)

GEORGE W. FULLER, qualified on behalf of complainants, substantially as follows:

Mr. Fuller is a resident of the city of New York, was educated at the Massachusetts Institute of Technology in Boston, and the University of Berlin, in Germany. While at the Massachusetts Institute of Technology he paid particular attention to the science of bacteriology, and also gave it considerable attention while at Berlin, both at the Hygienic Institute and in the private laboratory of the engineer in charge of the filter plant of the Berlin waterworks. He graduated from the Department of Chemistry in the Massachusetts School of Technology.

After returning from Europe and directly after his graduation he spent five years in the service of the State Board of Health of Massachusetts, and during the greater portion of his time was stationed at Lawrence, where an experimental plant

has been established for the purpose of determining the best way of purifying sewage in water. During this time he was engaged in experimenting with water and the influence of sewage upon water. From Lawrence Mr. Fuller went to Louisville and Cincinnati, where he was engaged in studying the best means of purifying the waters of the Ohio river as found in the river at those places. He had charge of extensive studies and investigations, during which time at least $150,000 was spent under his immediate charge, for the purpose of ascertaining the character of the Ohio river water and the best means of purifying it.

For the past four years he has been in private practice as a sanitary engineer and expert, and has made investigations in upwards of twenty-five or thirty different cities, among which is the city of Washington, D. C., where he was a member of the special committee appointed by the United States Senate committee of the District, which is in charge of treating the water of the Potomac river, the source of the water supply of that city. He was likewise engaged in Springfield, Mass.; Oswego, N. Y.; Meadville, Penn.; York, Penn., and Columbia, Penn., and through the group of cities lying directly west of New York, such as Paterson, N. J.; Passaic, Jersey City, Hoboken and others. He has also made extensive examinations in a number of places throughout the southern country, in Mexico, and on the far coast of Manzanillo.

Mr. Fuller is a member of the American Society of Civil Engineers, the American Chemical Society, the Society of American Bacteriologists, the American Public Health Association and the American Waterworks Association. As a member of the American Public Health Association he has given work relating to water supplies of cities and towns considerable attention. For a number of years he has been chairman of the

Committee of Purification of Water Supplies, and also of the committee having to do with the standard methods of water analysis.

(See Vol. 3, page 2602.)

ALLEN HAZEN, qualified on behalf of the complainant, as follows:

Mr. Hazen lives in New York City, his occupation being that of civil engineer. He resided in the city of New York for six years. He was born in New York and remained there until 1888, when he went to Massachusetts, where he remained until 1896, except one year, to wit, 1893, when he was engaged in work at Chicago. He was educated at the public schools of Hartford, Vermont, and the New Hampshire State College at Hanover; at the Thayers School of Civil Engineering, Hanover; the Massachusetts State Institute of Technology, and afterwards at the Technical School at Dresden, Germany. During his school years he studied chemistry, particularly the chemistry of water supply. He had direct charge of the Lawrence Experimental Station of the Massachusetts State Board of Health from the
51 time he left the Massachusetts State Institute of Technology until February, 1893. The character of his work at Lawrence was investigations as to methods of purifying sewage in water, and investigations of sanitary problems connected with water supplies and sewage. During the World's Columbian Exposition at Chicago he was in charge of the sewage disposal plant, and also had charge of the inspection of the drinking water used on the Fair Grounds. During his experiments and in his professional life he has been engaged in various undertakings. At Albany, New York, he advised regarding the water, particularly with reference to their supply and the means of improving it, and afterwards acted as engineer in charge of

the construction of their waterworks. At Albany the death rate of the city was exceedingly high, and this high death rate was caused by the sewage polluted condition of the water. A plant was built for the purpose of filtering the water supply. At Ithica, New York, he is now engaged in building a filter plant. He built the filtration plant at Harrisburg, Pa., and at West Superior, Wisconsin, and is now designing a filter plant at Watertown, New York, and is also engaged in building a filter plant at Yonkers. At Pittsburg, Pa., he advised the city government as to the character of their water supply and the best means of supplying the city with pure and wholesome water, and afterwards made plans for a filter plant for the city.

He has carried on extensive investigations at Providence, R. I.; Chester, Pa.; Trenton, N. J.; Toledo, Ohio; Grand Rapids, Mich.; Lancaster, Pa.; Millbury, Mass., and acted as consulting engineer for the Ohio State Board of Health; was engaged at Washington as a member of the commission composed of Messrs. Herring, Fuller and himself, which reported to the Senate committee of the United States on the water supply for the District of Columbia and the means of purifying it. More recently he has been engaged in the engineering corps at Washington with reference to the plans for the waterworks at that city, and has made plans for the filters of the city; the contract upon these plans has been let and the work begun.

Mr. Hazen worked with Prof. Sedgwick on the typhoid situation in Chicago in 1893, and after this work he secured ad-
52 ditional data, writing a paper jointly with Prof. Sedgwick upon typhoid conditions in Chicago. (See Vol. 3, pp. 2789 to 2796, inclusive.)

DR. EDWARD W. SAUNDERS, qualified for plaintiff, in rebuttal, as follows:

Dr. Saunders is a practicing physician at St. Louis, having been engaged in the profession there for 26 years; he attended and graduated from the University of Virginia in 1875, and since that time he has been practicing medicine in St. Louis, his office now being at No. 3007 Lafayette Avenue. (See record, Vol. 8, page 7857.)

DR. WASHINGTON E. FISCHEL, qualified as a witness in rebuttal for complainant, substantially as follows:

Dr. Fischel is a resident physician of the city of St. Louis, and has lived in this city all his life, and has practiced medicine since 1874; he is a graduate in medicine of St. Louis, Berlin and Vienna, graduating from the Washington University of St. Louis, the University of Berlin and the University of Vienna. At the time of his graduation from the Washington University the department from which he was graduated was "St. Louis Medical College." At the time of testifying he was connected with the St. Louis Hospital in St. Louis, and was consultant to the City Hospital, and lecturing to the classes in that hospital once a week, his lectures being given on medicine, or that branch known as clinical medicine. Both he and Dr. Saunders qualified themselves as being well acquainted with the disease known as typhoid fever and other water-borne diseases. (See Vol. 8, p. 7612.)

DR. LUDWIG BREMER, qualified as one of complainant's witnesses, substantially as follows:

Dr. Bremer resides at No. 3723 West Pine street, St. Louis, and is a practicing physician, having followed his profession in St. Louis for about 33 years. He studied at St. Louis Medical College, which is now known as the Washington University,

from which he was graduated in 1870. After his graduation he was connected with the city hospital of St. Louis. and later was resident physician of that hospital. He also studied at Strasburg and Zurich, Switzerland, and also at Paris on the subject of medicine. He also studied at Berlin and at Vienna, and has taught in the medical schools on the subjects of histology, pathologic anatomy, microscopy, biology and nervous diseases. Dr. Bremer is also credited with being the discoverer of the blood test for diabetes, and has written and published a number of medical and scientific articles. (See Vol. 8, p. 7623.)

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DR. ALBERT E. TAUSSIG, qualified, as a witness in rebuttal for complainant, substantially as follows:

He has lived all of his life in St. Louis, and is now a practicing physician in that city. He has, during his work, served for one year in the City Hospital. His office is now at No. 2647 Washington avenue. He graduated from the Smith Academy, a branch of the Washington University, in St. Louis, and received the degree of Bachelor of Arts at Harvard University, then took the degree of M. D. at the Medical Department of the Washington University, and then served a year as interne at the city hospital and a year and a half in the University of Berlin, taking both clinical and laboratory work. He is lecturer in medicine and senior instructor in clinical chemistry and microscopy in the Medical Department of the Washington University, and chief of one of the two medical clinics in the same University, and is now on the staff of St. Luke's Hospital, one of the principal hospitals of the city. (Vol. 8, p. 7637.)

DR. CHARLES H. GOODMAN, qualified as a witness in rebuttal for the plaintiff, substantially as follows:

Dr. Goodman resides at No. 3329 Washington avenue, and is a physician by profession, having been educated in St. Louis

and Philadelphia, and previous to receiving his professional degree he graduated at Yale University in 1867. He is a graduate of the Homeopathic Medical College of Missouri in St. Louis, and the Hahnemann Medical College in Philadelphia, having practiced in St. Louis for about thirty-five years. After having taught Theory and Practice for about five years in the
54 Medical College in Missouri, his position became for five years that of Professor of Theory and Practice. He is connected with the St. Louis Children's Hospital as attending physician and a member of the staff, and has been connected with this institution ever since its foundation, about twenty years ago. He has been a member of medical societies, local and outside, and is President of the City Medical Association, and the St. Louis Medical Association, the St. Louis Homeopathic Association, and enjoys a large and extensive private practice. (Vol. 8, p. 7657.)

DR. HERBERT E. SMITH, qualified for the complainants as a rebuttal witness, as follows:

Dr. Smith resides at New Haven, Connecticut, and is now Dean of the Yale Medical School, that is, the Medical Department of the Yale University. After the usual college preparatory course in the Hartford High School, he entered the Sheffield Scientific School of the Yale University, in the chemical and biological course, which is designed as a preparation for the study of medicine; then in the Medical Department of the Yale University he was laboratory assistant to Professor Benjamin Silliman. He then went to the University of Pennsylvania in Philadelphia, and received the degree of Doctor of Medicine in 1882. Immediately following he returned to Yale Medical School as laboratory assistant to Dr. Benjamin Silliman. At the end of that year he was appointed Lecturer in Chemistry in that

department, and retained that position for three years, meanwhile doing, besides his teaching there, a certain amount of research work in chemistry in the Sheffield School, and also worked at Heidelberg, Germany, where he did some special work at the university there. After the death of Professor Silliman he was appointed Professor of Chemistry in the Medical Faculty of Yale, which position he still holds, shortly afterwards being appointed Dean of the Medical Faculty, which position he also still holds. In about the year of 1890 he was appointed by the Governor of the State of Connecticut as one of the State Chemists for Connecticut, and became interested in waterworks and water analytical work, assisting the Connecticut State
55 Board of Health in the work which they were pursuing on rivers pollution in the State, and the examination of water supplies. After being associated with the Board for some time he was appointed Chemist of the Board and for fourteen years has had immediate charge of all the chemical and bacteriological work which the Board has done in connection with rivers pollution and examination of sewage and sewage effluent and drinking water. At Sheffield he received the degree of Bachelor of Philosophy. He has studied bacteriology, first becoming interested in this subject when he took up this branch of the work in 1887, and later, when bacteriology began to assume a considerable importance in connection with water supplies. He began to do personal work and has for a number of years done bacteriological work as it relates to the practical work of water examination. Dr. Smith was the first in this country to employ the use of the bacterial apparatus and methods which were originated by Dr. Koch, and is not only a chemist and bacteriologist, but thoroughly acquainted and familiar in a general way with the method and result of chemistry and bacteriology as applied to

water and sewage. He has been called upon and appointed in a number of cases by the State Board of Health of Connecticut and elsewhere to investigate epidemics that have occurred at Waterbury, Conn.; Hartford, Conn.; North Manchester, Conn.; Stanford, Conn.; Branford, Conn.; New Haven, Conn.; Bristol, Conn.; Forestville, Norwalk and Danbury, and has quite frequently been consulted in the ways of small epidemics at various places. (See Vol. 8, p. 7679.)

JOHN W. ALVORD, qualified on behalf of the plaintiffs in rebuttal, substantially as follows:

Mr. Alvord is a sanitary and hydraulic engineer, residing in the city of Chicago, Illinois, having been connected with the practice of his profession for about 24 years, with Chicago as a center, and following his profession in that city and various parts of the country surrounding. Mr. Alvord was ready for entrance to the Sheffield Scientific School of Yale College in 1877, but was unable to take the course at that time owing to poor health, and his engineering course has therefore been
56 confined to study and travel, coupled with practical experience. The first engineering work in which he was engaged was in 1879 in Chicago, in connection with the construction of the Hyde Park Pumping Station of the Chicago Waterworks and the Inlet Tunnel to such station under Lake Michigan. Later he was in charge of the operation of Lake View Station of the Chicago Waterworks, and was for four years City Engineer of Lake View, which was then a separate municipality from the city of Chicago, since then annexed. After the annexation of Lake View to Chicago he was engaged in general practice in sanitary work in the suburbs of Chicago and adjacent cities. He visited Europe in 1888 and 1894, and examined the question of water purification and sewage disposal particularly. From

1890 to 1893 he had charge of a department in the construction of the World's Columbian Exposition at Chicago, and in 1894 resumed private practice, since which time he has been engaged in various capacities in about thirty-five different city waterworks plants, and about forty-five municipal sewer systems, including the purification of water supplies and the disposal of sewage. In 1898 he was engaged in making a report to the city of Columbus, Ohio, on the extension of its sewer system and the disposal of its sewage, which report was published. From 1898 to 1902 he was consulting engineer to the Illinois State Canal Commission, advising as to the works of the Sanitary District channel in and through Joliet and in the litigation as to the removal of dams and locks at Joliet. He has recently been engaged in the development of water power at Petoskey, Mich., and Big River, Missouri, and Des Moines, Iowa. He has also been engaged in the designing of some twelve waterworks plants which have been constructed and in which the question of river pollution bore an active part. He has had considerable experience in typhoid epidemics, having studied them at Hurley, Wisconsin; Ironwood, Michigan, and Culver Academy, Indiana, in 1894, and the typhoid epidemic of Chicago, in 1892 and 1893; the Duluth epidemic of 1896, the typhoid epidemic at Grand Forks, North Dakota, in 1894, and he was engaged to investigate the causes of the epidemic at Wequetonsing, Michigan, and Petoskey, Michigan, in 1903. He is well ac-
57 quainted with the Chicago river, Chicago Drainage Canal, and the Illinois and Mississippi rivers. Mr. Alvord has given the question of bacteriology considerable attention in connection with his practice, and is also well acquainted with the science of chemistry as applied to water sanitation. He is a member of the American Association of Civil Engineers, and has been a member of that association since 1893, also a mem-

ber and trustee of the American Society of Civil Engineers and Surveyors, a member of the American Waterworks Association, the New England Waterworks Association, and the American Public Health Association, serving this year (1904) upon its Committee of Water and Sewage Purification.

(See Vol. 8, pages 7761 to 7794, inc.)

E. E. LOCHRIDGE, qualified as a witness for plaintiff in rebuttal substantially as follows:

Mr. Lochridge lives at Boston, Mass., and after graduating from the High School at Elkhorn, Wisconsin, graduated from Beloit College, in which he pursued courses in science, giving particular attention to the study of chemistry, receiving the degree of Bachelor of Science in 1898. During his senior year he acted as private assistant to Professor E. G. Smith, and under his direction studied questions of water supply with special reference to the water supply of cities and towns. Immediately after graduating from Beloit College he served as instructor in Chemistry for two terms at Drury College, Springfield, Missouri. He then returned to Beloit, having been appointed a regular instructor in Chemistry in Beloit College, but again served a larger part of his time as private assistant to Professor E. G. Smith in further work on water supplies, mainly from a chemical point of view. In 1900 he took the regular and some special courses in bacteriology at the University of Chicago, in the department presided over by Prof. E. O. Jordan. He then resumed his duties as private assistant to Professor Smith. In the course of his work he has had occasion to visit many private and public water supplies, and to examine such supplies and to study and investigate several epidemics of
58 typhoid fever, among which may be mentioned those at Rock Island, Illinois; Baraboo, Wisconsin, and Ashland,

Wisconsin, and has also studied the operation of filters for municipalities in a practical way at Davenport, Iowa; Cedar Rapids, Iowa; Rock Island, Illinois; Ashland, Wisconsin; Warren, Ohio; Kankakee, Illinois; Binghampton, New York; and two filter plants connected with the water supply of the Borough of Brooklyn, New York. During the years 1902 and 1903 he attended the Massachusetts Institute of Technology, in Boston, as a graduate student, taking the regular courses in sanitary engineering. He also, during his attendance at the Massachusetts Institute of Technology, in Boston, pursued advanced courses in bacteriology and sanitary science. In June, 1903, on the recommendation of Messrs. Samuel M. Gray and George W. Fuller, consulting engineers for the special commission on water supply of the city of Springfield, Massachusetts, he was appointed by that commission to make special studies on the question of purification of the water supply of that city. This work involved experimental investigation of the various methods of double filtration of water, and as resident engineer in charge of this work he had in his employ a number of trained assistants. (Vol. 8, p. 7821.)

IMPORTANT AND ESSENTIAL FACTS SHOWN AND ESTABLISHED BY THE EVIDENCE.

On account of the extreme length of the record, we have deemed it proper to call the court's attention directly to the essential propositions established, which entitles complainant to the relief sought. While we might extend the abstract of the evidence so as to consist of a large number of printed pages, we feel that a more complete and direct understanding of the entire controversy and the controlling facts can be gained by compressing it as much as possible.

1

WATER-BORNE DISEASES.

59

Water-borne diseases are produced by the effect of pathogenic micro-organisms upon the system of man or animal, and for convenience may be designated as

First: Typhoid Fever.

Second: Cholera.

Third: Dysentery.

Fourth: Vibrio Proteus, or a form of bacteria which produces a disease resembling cholera, but not true cholera.

Fifth: Bacilli Coli Communi, which may or may not be pathogenic, according to circumstances.

Sixth: Bacterium Tholoeideum, or a bacterium which before the application of the Weidal test produced a disease similar to typhoid fever. It is usually found in water suspected of causing typhoid fever, according to the statement of Dr. Frankland, a well known German scientist.

Seventh: Anthracis Spleenis. This Bacillus Anthracis or Spleenic Fever is among cattle, and as affects man producing malignant carbuncle.

Eighth: Proteus Vulgaris.

Ninth: Proteus Mirabilis.

Tenth: Proteus Zenkari.

Eleventh: Proteus Fluorescens. This bacillus is said to be pathogenic to some lower animals.

Twelfth. Tuberculosis or Tubercle Bacillus.

Thirteen: Bacillus Tetanus, which produces lockjaw.

All of which, together with a few others of minor importance, are set forth at pages 887-888-889 of volume 1 of the printed testimony.

The principal water-borne diseases may be designated as cholera, typhoid, dysentery, anthrax and tetanus, and the results produced by Bacillus Coli Communis when injected under the skin of a human being, or when lodged in the appendix producing appendicitis. Typhoid fever or Bacilli Ty-
60 phosis is a common water-borne disease in this country. It is caused by crude sewerage being discharged into the water supply. This fact is demonstrated by the effect of the establishment of filtration plants for the purpose of treating the water supplied the cities of Hamburg, Germany; London, England, and Berlin, Germany, and in a number of large cities in this country.

(Printed record, volume 1, pages 446, 749-750-752.)

It is needless to discuss the question as to whether or not typhoid, cholera, dysentery, anthrax and tetanus are water-borne diseases, as this proposition is conceded by the witnesses who testified on behalf of either side of the case. In fact, sanitary science has come to realize with absolute assurance that the diseases above mentioned as a general thing are caused by in-

ferior water, or water which has been subjected to sewerage pollution.

While it is practically impossible to discover or detect the physical presence of bacillus in running water, save or except as to Bacilli Coli Communis, which is found in abundance in all streams in which sewerage is emptied. All persons having knowledge of sanitary science have settled beyond question that the diseases above mentioned are, as a general proposition, more readily communicated by means of inferior water supplied than in any other way.

In the examinations of the water of the Illinois river the Bacillus of Tetanus and of Anthrax was discovered in the water of that river. This, in connection with Bacilli Coli Communis, which is very prevalent in the water of the Illinois, as shown by all the testimony in the case, constitutes practically the total results of the discoveries of the pathogenic bacillus in the waters of the rivers in question during this entire investigation.

2

CHOLERA.

Cholera is known to be a germ disease, and was discovered in India in 1885 by Dr. Koch. In his investigation of the condition in India Dr. Koch found the cholera germ to be contained in the water of one of the tanks from which water was
61 drawn by the people for domestic purposes. He studied the germ under various laboratory conditions, and found that it would live an indefinite number of days in various kinds of water, subject to change of temperature. He found that it takes a temperature of boiling water to kill it, and that it will stand an indefinite period of freezing. While freezing will not destroy this germ, yet alternate thawing and freezing will eliminate a great many of them. The germ is highly active and belongs to that class known as motile or swimmers.

(Printed record, Volume 1, pages 28-29-30.)

It increases very rapidly in the human system, but no experiment so far shows that it multiplies in living water. It is a water-borne disease, and is, therefore, contagious. It retains its vitality for quite a while when it is dried. It will float in the air after dried, and remain virulent for a long time. It infects the water supply and is communicated by that means to the people.

(Printed record, Volume 1, pages 48-49.)

3

EPIDEMIC OF CHOLERA.

Dr. Ravold testified as to his familiarity with cholera epidemic at Hamburg, Germany, in 1892. The Jews were being driven from Russia and some of them settled on the quay at Hamburg, waiting for ships to transport them to the United States. There happened to be cholera among them and they remained upon the banks of the river Elbe, below the waterworks. The tide in the river carried the water from the point where they resided up stream, where it was conveyed into the intake of the Hamburg water supply. The unfiltered water was used for domestic purposes. In the course of several days about 18,000 cases of cholera developed. Altoona, a town situated immediately below Hamburg, perhaps about twenty miles, where the water is taken from the Elbe river below the sewers of Hamburg, Altona, nevertheless, was free from cholera, except among those who drank water in Hamburg and lived in Altoona.
62 Later a break occurred in one of Altoona's sand filters, and a flurry of cholera followed the break until it was corrected, when the disease disappeared.

This is one of the most beautiful examples in the world of water-borne diseases being carried by water supply. Professor Koch was called to Hamburg and studied the water supply of both places. He found the cholera bacilli in the water of the Elbe.

4

TYPHOID FEVER, HOW CONTRACTED.

Typhoid fever is caused by a micro-organism, discovered by Ebert and Koch, independently, in the intestinal wall of persons dead of the disease, and later studied by Graffky, who had separated it out into pure cultures, so that it is known as the Koch-Ebert-Graffky bacillus, or the typhoid bacillus.

This micro-organism is found in the intestinal canal of people sick of the disease; in the fallicles and lympathics of the mucous membrance of the intestines; in the messenteric glands; in the spleen; in the liver; in the kidneys; flowing in the blood; sometimes in the rose spots or eruptions that occur on the skin; in the brain, and it is discharged from the body in the feces and in the urine.

No animal other than man suffers with typhoid fever, and in order for him to have the disease it must be taken into the intestinal canal, either through the mouth or through the nose, thence through the throat into the alimentary canal. In the alkaline fluids of the small intestines it finds a congenial habitat and grows and multiplies enormously, producing toxins, which coming in contact with the mucous membrane of the intestines, especially the mucous membrane near the lymphatic glands or the lymphatic tissues themselves, causes an exfoliation of the superficial cells, making a way for the entrance of the micro-organisms into the lymphatic stream and thus into the various organs above set forth, and in which the micro-organisms are usually found.

63 There are a variety of ways by which the bacillus typhosus is conveyed to the alimentary canal of man.

1st. By drinking water contaminated with the micro-organism.

2nd. The micro-organism may be contained in the dust that is blown around and thus conveyed through the nose.

3rd. By direct conveyance from sick to well persons nursing an individual sick of the disease. In handling the bed clothes, or soiled linen or other material about the patient attendants may have their hands inoculated with it and thus convey it into their mouth by picking their teeth, or picking their nose, or, without washing their hands, go to the table to eat, and in this way convey it directly to their mouth.

4th. It may be carried in food, such as raw oysters fed at the mouth of a sewer. Conn of Wellesley showed that an epidemic of typhoid fever was produced by eating raw oysters which had been fed at the mouth of sewers.

5th. It may be conveyed by flies, as was shown to be the case among the soldiers in the typhoid epidemic that broke out among those stationed at Chickamauga and Jacksonville, Fla. It was there discovered that swarms of flies would feed in the latrines in which the dejecta of the men were thrown, and that as soon as the mess was served, the food cooked and served on the tables, the flies left the latrines in swarms and carroled all over the food of the soldiers, carrying the infective feces with them. Professor Vaughn, and others skilled in that line, who investigated the epidemic at that place, became convinced that flies were in a large measure instrumental in causing the epidemic, the bacilli being carried upon the feet of the flies from the latrines to the food upon the table.

6th. It is also conveyed by vegetable, such as lettuce or celery, sprinkled with water containing typhoid germs.

7th. Secondary infection: Where the germ finds its way into prepared food, such as potatoes, broth of all kinds and milk,

which at the proper tempertaure causes them to increase and multiply very rapidly. In this way large numbers of the micro-organisms are taken into the system.

64 (Dr. Ravold's testimony, printed record, Volume 1, pages 830-832.)

The most active means of contracting typhoid fever is by the use of typhoid infected water for domestic and drinking purposes.

5

TYPHOID FEVER EPIDEMICS.

One of the most satisfactory means of demonstrating the fact that typhoid fever is a water-borne disease is by a careful study of the various typhoid epidemics and an examination into the source of the infection.

ST. LOUIS.

Prior to 1892 the intake of the St. Louis water supply was at Bissell Point, which lies immediately north and above what now is known as the "Merchants' bridge." The sewerage from the city was discharged into a small stream immediately above Bissell Point. This stream is known as Harlem creek. A severe typhoid epidemic broke out in St. Louis in the early part of 1892. Upon investigation it was found that the sewerage from Harlem creek entered the Mississippi river about 1,000 feet above the intake at Bissell Point. This was observed by Dr. Ravold, according to his testimony in the printed record, Volume 1, page 408, where he said "black, oily looking water that was discharged from Harlem creek ran into the yellow water of the Mississippi river at this point and could be seen floating down the river, clinging to the shore on the Missouri side, and could be seen at times running directly into the intake. I have stood on the bridge several times with other gentlemen—other physicians—and looked at it."

As soon as it was determined that the typhoid fever was caused by the water from Harlem creek flowing into the intake, a dam was constructed across the creek and pumps used

65 for the purpose of conveying the water into the Mississippi river, a point below the intake. As soon as this was done the typhoid epidemic at St. Louis for the year 1892 terminated. So severe was this epidemic that for the fiscal year ending in April, 1893, 3,624 cases of typhoid fever were reported to the health authorities by the physicians of the city, with a total number of deaths of 514.

(Printed record, Volume 1, page 410.)

LAUSEN.

At Lausen, Switzerland, an epidemic of typhoid fever occurred in August, 1872. Lausen is situated at the foot of Stockholm. It contained about seven hundred people. The water used for domestic purposes was obtained from a spring at the foot of this mountain, the water being conducted from the spring through pipes to the fountain in the town. In August, 1872, the first case of typhoid fever occurred in Lausen, and within a very short period 140 cases occurred. In the investigation it was found that Fuerlin brook was being discharged through the mountain as a natural filter, and that the water in the spring at Lausen had become slightly turbid and considerably increased in its flow. After a time this brook became again confined to its course and the hole that appeared in the side of the mountain was filled up. The brook being used in the summer time for irrigating the fields below. In June of that year a family, consisting of three persons, were afflicted with typhoid fever near the banks of Fuerlin brook; following this came the typhoid epidemic. Dr. Haegler undertook to discover whether or not the infected water passed down through this mountain to the spring below. In other words, whether the infected water from Fuerlin brook passed through the mountain to the spring. He put 5,000 pounds of salt in the hole and chloride of sodium

was easily detected from the water which emptied into the spring. He also emptied several hundred pounds of flour into the brook, but none of it came through, there being no starchy particles detected in the water of the spring. It was also known that there was no typhoid fever in that district for
66 some sixty years before, except the three cases above referred to. The water carrying the typhoid fever germ was therefore required to pass through the mountain for a distance of about a mile, which it did, and so thoroughly contaminated the water of the spring with typhoid fever as to cause the epidemic.

(Printed record, volume 1, pages 463-464-465.)

PLYMOUTH, PENNSYLVANIA.

In 1885 an epidemic of typhoid fever occurred at Plymouth, Pennsylvania, there being 1104 cases in the town, which contained a population with scarcely 8,000 inhabitants. Upon investigation it was found that this epidemic was caused by germs of the disease being discharged upon the banks of the reservoir, from which the water supply was obtained.

(Printed record, volume 1, pages 465-466.)

LAWRENCE, MASSACHUSETTS

In 1896 an epidemic of typhoid fever broke out at Lawrence, Massachusetts. This was investigated by Professor W. T. Sedgwick, who arrived at the conclusion that the epidemic was caused by typhoid fever germs being discharged into the Merrimac river, from which the town obtained its water supply.

(Printed record, Volume 1, page 467.)

The Plymouth, Pennsylvania, epidemic is described by Prof. Sedgwick, as follows:

The most celebrated and important epidemic in this country was one which happened at a little mining town in Pennsylvania in 1885. On the watershed of that town they had built four storage reservoirs, and on the bank of the stream which supplied the uppermost of those reservoirs a case of typhoid fever appeared in the early spring of 1885. The reservoirs had all been drawn very low, owing to a cold spell which they had had, and on the arrival of the spring thaw 1,200 cases of typhoid fever broke out in this little town of 8,000 inhabitants. These
67 were traced—and it is believed by sanitarians were correctly traced—to the occurrence of the one case of typhoid fever on the banks of the uppermost reservoir, followed by the washing in during a thaw of the dejecta of that patient in the low stage of the reservoir and the rapid transmission to the people of that town. It was a dramatic and a terrible event. (Sedgwick's evidence, Vol. 3, page 2206.)

LOWELL.

In the autumn of 1890, Prof. Sedgwick was called to investigate an epidemic of typhoid fever in the city of Lowell, Mass. After preliminary study he was led to the conclusion that the epidemic in question was caused or had been caused by typhoid fever infection of a small, sluggish stream which entered the Merrimac river, a larger and much swifter stream almost at right angles. It was found that the infection of the water of the smaller stream had mingled with the water of the larger stream, so that at a point three miles below the entrance of the smaller into the larger stream, where the city of Lowell had its intake, the infectious material was received, and from that place was borne into the water supply, producing an epidemic of over 1,000 cases of typhoid fever. While the epidemic was very severe at Lowell, it was also believed by the persons making the

examination that it produced the epidemic at Lawrence, nine miles below. (Sedgwick's testimony, Vol. 3, pages 2200, 2201 and 2231.)

NEWBURYPORT.

This epidemic was caused by drinking typhoid infected water, twenty or thirty miles below Lowell. (See record, Vol. 3, page 2207.)

WINDSOR, VERMONT.

In 1892, or 1893, Prof. Sedgwick was sent to Windsor, Vermont, by the State Board of Health of Massachusetts to
68 observe the epidemic at that place. Windsor is a summer resort, and the water supply is derived from a dammed brook. The epidemic was occasioned by the typhoid dejecta of one patient upon the watershed above. (Record, Vol. 3, page 2208.)

PITTSBURG.

In 1898 a special study of typhoid fever was made at Pittsburg, Pa. Acting on the advice of one of the most eminent engineers of the time, Pittsburg introduced a water supply drawn from the Alleghany river mainly. The Alleghany river is a swift stream, with remote pollution, there being no near pollution of any moment. Oil City, 113 miles above, being the first important point which might be considered dangerous from the standpoint of typhoid infection. The result, however, of even that remote pollution was that after a careful study of the epidemic, prolonged for several weeks, a recommendation was made to the city of Pittsburg that a filtration plant be put in. (See Vol. 3, page 2208.)

NEW HAVEN, CONN.

Another serious epidemic, due to pollution on the watershed of a public water supply, is that of New Haven, Conn., in 1900. The city of New Haven obtains part of its water from a certain inhabited watershed, not thickly inhabited, but under conditions similar to those of Pittsburg, Pennsylvania. Their reservoirs had been drawn down low, owing to a freeze. In the spring a thaw came, which was followed by a big rain, with the result that typhoid micro-organisms were washed from a house on the watershed where there had been a few cases of typhoid fever. They were carried into the large storage reservoirs, resulting in 470 cases of typhoid during that spring. The cause of this typhoid epidemic was traced by Dr. Smith, Dean of Yale Medical College, and proved—as far as anything can be proved of this kind—that the probable cause of the epidemic was, as above stated, by the germs of typhoid being carried into the reservoirs. (See Vol. 3, page 2209.)

69

DETROIT.

The water supply of the city of Detroit, Mich., is drawn from the American channel of the Detroit river. The intake is situated at the head of the river, or near the foot of Lake St. Clair. The water from Lake Huron enters St. Clair river, flows through it a distance of 35 miles to the delta of the St. Clair river, where it discharges into Lake St. Clair. Lake St. Clair is circular in form, being about 24 miles wide, including its delta, and 24 miles in length. The water supply of Detroit is taken practically from the lake, or from the river a few hundred feet below where it takes its origin in Lake St. Clair.

In the year 1890 the number of deaths in Detroit from typhoid fever were 39, and in 1892 the number rose to 209. This remarkable increase was such as to cause Detroit for that year to take rank among those cities which have had the highest death rate for typhoid fever in America. An examination of the records showed the epidemic began in June, during which month there were 38 deaths from typhoid fever. As civil engineer to the Board of Water Commissioners of Detroit, Mr. Gardner Williams commenced an investigation for the purpose, if possible, of determining the source of the remarkable infection. After an extended investigation he ascertained that the epidemic was caused by an improvement to the channel of Black river, which flows into St. Clair river near its head at Port Huron, a distance of 57 miles from the intake of the Detroit waterworks. Black river is a sluggish stream, having ordinarily no current, the current being perceptible only in times of heavy rain. For years the city of Port Huron had been discharging its sewage into Black river. In order to improve the harbor at Port Huron, the United States government had caused the river to be dredged during the early months of 1892. In the process of that dredging the deposits in the river near the mouth of the sewers had been removed, these deposits ranging in depth from one to eight feet. The material was loaded on scows, transported out into Lake St. Clair and in the St. Clair river, and there discharged or dumped into the stream. The investigation disclosed that this work was begun in such time and under such conditions that the infectious deposit of material was dredged and deposited in the St. Clair river so as to fully explain the cause of the outbreak of typhoid fever in Detroit after having been carried through the waters of St. Clair river and through Lake St. Clair to the intake of the waterworks. St. Clair river at the point where the

material was dumped is about 1,800 feet wide and from 30 to 36 feet deep. It passed thence into Lake St. Clair, which has an average depth of about 16 feet, there being no perceptible current in the lake, though St. Clair river is quite a swift flowing stream. The time elapsing between the deposit of the infectious matter from Port Huron and the arrival of the water into which it was discharged, and the delivery of the same to the consumer in the city of Detroit would be the time required for water to flow from St. Clair river, where the deposit was made, to the intake in Detroit, and to be distributed throughout the city to consumers. Mr. Williams estimated this time carefully and found it could not be less than eight days, and not more than fourteen days, ten days being a fair estimate of the time required. According to the best evidence, the period of incubation of typhoid fever is from seven days to four weeks, seventy-five per cent of the cases, perhaps, incubating in from ten to fifteen days. It was found by making allowance for the time required for the infection to come from the point at Port Huron, where the material was discharged into the lake, to the consumers of water in the city of Detroit, allowing the average period of incubation for typhoid fever, and allowing the ordinary time to elapse between the taking down of the patient and the occurrence of death, that the sum of such times agreed within twenty-four hours of the time which had elapsed from the deposit of the dredged material from Black river into the St. Clair, and the occurrence in a single day of four deaths in Detroit from typhoid fever, there having been only one death in the preceding twenty-four days. (See Williams' testimony, Vol. 3, pages 2439 to 2445, inclusive.)

GRAND FORKS, NORTH DAKOTA.

The main sewer of the town of Crookston, Minn., became damaged in the fall of 1893, so that it failed to discharge
71 the material delivered into it. This led to the accumulation in the sewer of deposits of sewage matter, and to afford temporary relief a small connection was made around the break, which carried off a portion of the liquid matter of the sewage and discharged it into Red Lake river, which was the stream into which the sewage of Crookston was regularly discharged. In the fall of 1893 the sewers were repaired and on November 17th the sewage system of Crookston was flushed of the accumulations which had gathered during the several months preceding. Typhoid fever to the extent of about sixty cases had existed in Crookston in October and November, 1893. At the time of the flushing of the sewers and consequent delivery of the sedimentary accumulations from them into Red Lake river, the river was frozen over. The town of Grand Forks, North Dakota, is located about sixty miles by the river below Crookston, on Red river. In November there were in Grand Forks two cases of typhoid fever and no deaths, and for the month preceding there had been a very small amount of typhoid fever. In December following the flushing of the sewers in Crookston on November 17th, there were reported 230 cases of typhoid fever and four deaths in Grand Forks, in January 712 cases and 52 deaths; in February 231 cases and 27 deaths; in March 46 cases and 11 deaths; in April 26 cases and 2 deaths; in May 1 case and no deaths; showing apparently that the epidemic had expended itself by the close of the month of April, and that there were in the neighborhood of 1,200 cases and nearly 100 deaths, as the result of flushing the sewers at Crookston, sixty miles up stream

from Grand Forks. (Williams' testimony, Vol. 3, pages 2455 and 2456.)

The evidence of Drs. Willis, C. B. Stockwell, Oliver Stewart, E. J. Haynes, Vol. 3, pp. 2690, 2715, 2720, 2745, together with the testimony of F. R. Rogers, Vol. 3, page 2730, is to the effect that prior to the typhoid epidemic at Detroit it was investigated by Mr. Williams, who found a variable number of typhoid fever deaths, and a larger number of cases of typhoid occurred in the city of Port Huron, and that this typhoid death rate was continuous from year to year for at least thirty years prior to 1892. Black river is shown to pass directly through the
72 town of Port Huron. The matter which had sedimented in front of the city became so extensive that it was necessary for the government of the United States to dredge in front of the city in order to admit navigation at the mouth of Black river. This is described by Mr. Williams as the immediate cause of the typhoid epidemic at Detroit following some weeks after the dredging. The territory surrounding Port Huron and Detroit was thoroughly investigated for the purpose of determining whether or not the typhoid epidemic had taken place on the watershed above the city, and every available means was employed to ascertain the true source of the infection, the final and ultimate conclusion being that it could be attributed to no cause other than the dredging of the river at Port Huron.

WASHINGTON EPIDEMIC.

It is a well known fact that the polluting and infectious matter contained in the Potomac river at Washington was derived largely from Cumberland, Maryland, a city situated upon the Cumberland river, 175 miles above Washington. In January, February and March of 1890, Cumberland suffered a typhoid epidemic which became very extensive; the result of this was

that within a short time typhoid fever appeared in Washington City. In January there were 18 deaths from typhoid at Cumberland, in February 27, in March 29, in April 8 and in May 5. The effect of this was that the epidemic became current in March in Washington, the total deaths from typhoid being 19, and this epidemic extended through to August, the number of deaths being as follows: March 19, April 11, May 13, June 33, July 36, August 28. This epidemic is particularly interesting and has been repeatedly referred to in public meetings, and in hearings before congressional and other committees at Washington. It is a very instructive example of the transmission of typhoid fever through polluted streams, for the reason that Cumberland is about 175 miles from Washington by river, the river being of such a character as to offer a good example of a stream not very swift or not very slow, having occasional stages of slack water which are succeeded by steeper portions, there-
73 fore offering a good opportunity for the so-called self-purification. Washington has no doubt an excessive death rate from typhoid fever. It has been repeatedly attributed in part by competent experts to the use of Potomac river water for drinking purposes. During March, 1890, through to August of the same year, the cases of typhoid reached extraordinary proportions, so much so that if the typhoid deaths of these months are compared with the average typhoid mortality for the five years previous and the five years afterwards, it appears to have amounted to about 100 per cent; that is to say, that in addition to the ordinary typhoid mortality of Washington, there was apparently owing to this epidemic in Cumberland a further excess of about 100 per cent. So clear was this connection regarded by local authorities and by experts that when a case of Asiatic cholera was reported to have appeared in Cumberland, Maryland, in 1894, great uneasiness was felt by the experts in Wash-

ington, though fortunately the case proved to be something else than Asiatic cholera.

The question naturally following is, how long does it take water to flow from Cumberland to Washington, and this has been variously estimated, and has been given by Capt. Gaillard of the U. S. Engineers, in Senate document No. 94, 55th Congress, second session, as from four to seven days from Cumberland to the intake.

It is also true in connection with the epidemic in Washington in 1890, following the epidemic in Cumberland, Maryland, in the same year, that the excess of deaths from typhoid fever in Washington is not clearly marked until about two months after the outbreak in Cumberland. That is to say, while there were 18 deaths in Cumberland in January, 1890, no marked excess appears in Washington until March. Furthermore, while the epidemic in Cumberland ended in May, that in Washington was continued vigorously during July and even to some extent in August. Whether this delay in the instance of deaths in Washington is or is not due to the temporary deposit of germs in the bed of the stream to which they were afterwards returned from the flowing water and delivered in Washington, it is impossible to say positively, but it is difficult to resist the feeling that this may have been the case. It is certainly a remark-
74 able and interesting fact. We know, to be sure, that persons who have had typhoid fever continue, even after recovering, often for considerable periods, to discharge germs from the body, and it may have been that the tardy appearance in Washington was due to this cause. It will also be noted in this connection that after allowing time for the passage of the germs from Cumberland to Washington and the period of incubation and time for the death of the patient that there is a

remarkable concurrence between the two epidemics, the one following properly after the other. (Sedgwick's testimony, Vol. 3, 2759-60-1-2-3. See also testimony of Dr. W. W. Wiley and Dr. W. C. Woodward, Vol. 3, pages 2857 and 2878.)

6

BACILLI COLI COMMUNIS.

Where the bacillus coli communis is present in running water in such numbers that its presence can readily be determined by analyzing one cubic centimeter or less of water, it is an indication of contamination by foecal matter, and therefore is a valuable test in connection with the chemical analysis of water for the purpose of determining its sanitary qualities. (Whipple, cross-examination, Vol. 3, pages 2375-6-7.)

Bacilli coli communis, as a general proposition, is considered non-pathogenic. It becomes pathogenic, however, when injected under the skin or when it gets into the blood stream or lymphatic stream from the intestinal canal. It is one of the most active causes of appendicitis.

(Dr. Ravold's testimony, printed record, Volume 1, page 801.)

An examination of the fish contained in the waters of the Missouri, Mississippi and Illinois rivers discloses the fact that the bacilli coli communis is contained in fish in the Illinois river in large quantities, and to some extent in the fish in the water of the Mississippi river, but was not found in the fish in the water of the Missouri river. It is not, however, a natural habitat of fish, but eighty per cent. of the fish examined from the Illinois river were found to contain it.

75 (Dr. Ravold's testimony, printed record, Volume 1, pages 25 and 26.)

There is no record of it ever having been found in fish before this investigation.

(Printed record, Volume 1, page 68.)

The samples of water taken during the months of May, June and July, 1900, show that bacilli coli communis were found in the water of the drainage canal in 87 per cent. of the samples analyzed, and during August, September and October, 1900, 100 per cent. of the samples contained coli.

(Dr. Ravold's testimony, printed record, Volume 1, page 98.)

During the second period, or during the year 1900, it was found to be contained in 99 per cent. of the samples of water analyzed from the drainage canal, and during the third period at Joliet it was found to exist in 79.2 per cent. of the samples examined. At Rubey Street Station, Joliet, from September 26th to November 25, 1901, coli was found to be present in 83 per cent. of the samples examined. At Brandon's Bridge, Joliet, it was found to be contained in 79 per cent. of the samples examined.

(Dr. Ravold's testimony, printed record, Volume 1, pages 231-233.)

During the month of October, 1901, coli was found in 87.1 per cent of the samples of water taken from the Illinois river three miles above Peoria, and in November, 1901, of the water taken from the river three miles above Peoria it was found in 79.1 per cent of the samples analyzed.

(Dr. Ravold's testimony, printed record, Volume 1, pages 232-233.)

At Grafton, at the mouth of the Illinois river, during the month of October and November, 1901, it was found in 53.6 per cent of the samples examined, and during the same month it was found in but 47 per cent of the samples examined from the Mis-

sissippi river above Grafton, and above the mouth of the Illinois. There is much less coli in the waters of the Missouri river than in that of the Mississippi and the Illinois rivers, as shown by the testimony of Dr. Ravold, printed record, volume 1, pages 252-259, inclusive.

(Printed record, Volume 1, page 890.)

76

7

BACTERIAL CONTENTS OF ILLINOIS, MISSISSIPPI AND MISSOURI RIVERS COMPARED, SHOWING THE EFFECT ON THE LAKE MICHIGAN WATER AND THE SEWERAGE OF CHICAGO UPON THE WATERS OF THE ILLINOIS RIVER AND OF THE MISSISSIPPI RIVER BELOW THE MOUTH OF THE ILLINOIS RIVER FROM A BACTERIOLOGICAL STANDPOINT.

Three periods of scientific bacterial determinations of the waters of the Mississippi, Missouri and Illinois rivers were made for the purpose, if possible, of determining the effect the water of the Illinois river had upon the St. Louis water supply. Samples of water were collected at various points on the respective rivers, which were put to chemical and bacteriological tests.

During the first period, to wit, from August 23rd, 1899, to January 23, 1900, samples of water were collected at the following named places on the rivers in question:

Mississippi river,

Chain of Rocks, 300 feet from the Missouri shore.

Chain of Rocks, 300 feet from the Illinois shore.

Chain of Rocks, Intake Tower, about 1,500 feet from the Missouri shore.

St. Louis Distributing Well.

Madison Landing, immediately below the mouth of the Missouri river.

Missouri river at its mouth.

Mississippi river below Alton.

Mississippi river near Clifton Terrace above Alton.

Mississippi river immediately below Grafton.
Illinois river above Grafton.
Mississippi river above Grafton.

(Printed record, Volume 1, page 641.)

During the second period, which began on the 23rd day of
77 January and ended on the 23rd day of November, 1901, samples of water were collected from

Lake Michigan,
The Illinois and Michigan Canal at Lockport,
Chicago Drainage Canal above Bear Trap Dam,
Des Plaines river at Joliet,
Des Plaines river above the entrance of the Chicago Drainage Canal,
Illinois river three miles above Grafton,
Illinois river at Wesley, Illinois, immediately below,
Illinois river three miles above Pekin bridge,
Mississippi river two miles above Grafton,
Mississippi river at Hartford below Alton,
The Missouri river at Fort Bellefontaine,
Mississippi river at Chain of Rocks, three hundred feet from Missouri shore,
Mississippi river, Chain of Rocks, three hundred feet from Illinois shore,
Mississippi river, Chain of Rocks, Intake Tower, 1,500 feet from Missouri shore,
St. Louis Waterworks outlet chamber,
St. Louis water tap at City Chemist's office in the old city hall.

During the third period from October 1, 1901, to November 30, 1901, samples of water were taken during this period from

Illinois and Michigan Canal at Bridgeport,

Chicago Drainage Canal at Bridgeport,
Chicago Drainage Canal at Lockport,
Chicago Drainage Canal immediately above Bear Trap Dam,
Illinois and Michigan Canal at Lockport,
Des Plaines river above Bear Trap Dam,
Des Plaines river above Ninth Street Tower at Joliet,
Des Plaines river at Rubey Street Station, Joliet,
Des Plaines river at Brandon's Bridge, Joliet,
Illinois river at LaSalle, Illinois,
Illinois river three miles above railway bridge at Peoria,
Illinois river at Pekin,
78 Illinois river at Kingston eight miles below Pekin,
Illinois river at Grafton,
Mississippi river at Grafton,
Mississippi river at Alton,
Mississippi river at Hartford below Alton,
Mississippi river, Chain of Rocks, mid-stream,
Mississippi river, Chain of Rocks, three hundred feet from Missouri shore,
Mississippi river, Chain of Rocks, three hundred feet from Illinois shore,
Missouri river at Fort Bellefontaine,
St. Louis Waterworks, outlet chamber,
St. Louis Waterworks tap in office of City Chemist at City Hall.

(Printed record, Volume 1, page 665.)

During these periods, samples of water were collected daily and immediately analyzed for the purpose of obtaining their chemical and bacterial contents.

In addition to this, cross-sections of the samples of the waters of the Mississippi, Illinois and Missouri rivers were taken at the following respective points:

Mississippi river, Chain of Rocks,
Mississippi river at Alton,
Mississippi river at Hartford,
Missouri river at Fort Bellefontaine,
Illinois river at Pekin,
Illinois river at Kingston,
Illinois river at Peoria,
Des Plaines river at Joliet.

These cross-sections were taken by dividing the rivers into ten or twelve equal portions, and taking samples of water from the respective points.

(Printed record, Volume 1, pages 57-58, 64, 111-114, 666-667.)

During the first period of examination in the year 1899, the average bacteria per C. C. in the water of the Mississippi river at the up-take at the Chain of Rocks was 489.

79 (Dr. Ravold's testimony, printed record, Volume 1, pages 80-81.)

During the same period, 1899, at Wheeler's Ferry on the Illinois river, three miles above its mouth, the average of 162 bacteria per C. C.

Illinois river, five miles above its mouth, 160 bacteria per C. C.

Mississippi river at Grafton above the mouth of the Illinois river, 190 bacteria per C. C.

Mississippi river six miles above Alton, 276 bacteria per C. C.

Mississippi river, Chain of Rocks, 160 bacteria per C. C.

Missouri river at its mouth 1,070 bacteria per C. C.

During the second period of investigation the average daily count at Bear Trap Dam was 1, 825,000 bacteria per C. C., 200

daily tests being made. While the average daily count of bacteria for eight days immediately following opening of the canal was 20,663,000 bacteria per C. C.

(Dr. Ravold's testimony, printed record, Volume 1, pages 100-106.)

Lake Michigan disclosed 37,700 bacteria per C. C., with coli communis present in 66—2-3 of the samples examined.

At the Four Mile Crib during the second period of examination in 1900 the bacterial contents of the water of Lake Michigan was 47,500 bacteria per C. C.

At 68th Street Crib, Lake Michigan, the bacterial contents of the water disclosed 82,000 bacteria per C. C.

(Dr. Ravold's testimony, printed record, Volume 1, pages 94-96.)

For the week of January 30, 1900, the bacterial contents of the water of the Illinois river at Grafton, as shown by the investigation made by Dr. Ravold, disclosed 116,000 bacteria per C. C.

For the week of February 6, 1900, 109,000 bacteria per C. C.

80 For the week of February 13, 1900, 257,000 bacteria per C. C.

For the week of February 20, 1900, 221,000 bacteria per C. C.

For the week of February 27, 1900, 223,100 bacteria per C. C.

For the week of March 6, 1900, 267,700 bacteria per C. C.

For the week of March 13, 1900, 239,000 bacteria per C. C.

For the week of March 20, 1900, 204,000 bacteria per C. C.

For the week of March 27, 1900, 151,000 bacteria per C. C.

(Printed record, Volume 1, pages 353-354.)

Dr. Ravold's bacterial examination of the water of Lake Michigan during the second period discloses the following results:

Four Mile Crib, one of the intakes of the water supply of Chicago, Lake Michigan, 1,600 bacteria per C. C., with coli communis present.

The Carter Harrison Crib, located about ten miles from Chicago, Lake Michigan, on July 30, 1900, disclosed 12,300 bacteria per C. C., with the coli communis present.

The samples of water being taken ten feet below the surface. The crib not being ten miles out in the lake, but the samples of water were taken that distance in a direct line with the crib and the city.

(Dr. Ravold's testimony, printed record, Volume 1, page 94.)

On August 9, 1900, the samples of water at a point ten miles in Lake Michigan disclosed 16,300 bacteria per C. C., with coli communis present.

During the second period the bacterial examination of the water at Carter Harrison Crib, in Lake Michigan, disclosed 16,850 bacteria per C. C., with coli communis present.

At Lake View Crib, Chicago, the determination during this period resulted in a disclose of 4,650 bacteria per C. C.

At Two Mile Crib during the second period of the investigation the bacterial contents of the water was 308,466 bacteria
81 per C. C., with coli communis present in 66—2-3 of the samples examined.

The effect of the sewerage of Chicago upon the water of the Mississippi river is shown by the bacterial contents of the water at Hartford, seven miles below Alton and one mile above the union of the Missouri and Mississippi rivers, during the

second period of examination in the months of January, February and March, 1900, is as follows:

For week ending January 30, 1900, 87,500 bacteria per C. C.

For week ending February 6, 1900, 147,000 bacteria per C. C.

For week ending February 13, 1900, 160,500 bacteria per C. C.

For week ending February 20, 1900, 233,500 bacteria per C. C.

For week ending February 27, 1900, 266,900 bacteria per C. C.

For week ending March 6, 1900, 193,000 bacteria per C. C.

For week ending March 13, 1900, 209,000 bacteria per C. C.

For week ending March 20, 1900, 320,500 bacteria per C. C.

For week ending March 27, 1900, 227,600 bacteria per C. C.

(Dr. Ravold's testimony, printed record, Volume 1, page 358.)

It will be well to remember in this connection that the drainage canal was opened on the 17th day of January, 1900.

During the same period, to wit, the second period of investigation, the bacterial determination of the waters at Intake Tower, Chain of Rocks, about one hundred feet in front of the tower, the weekly result of the investigation is as follows:

For the week ending February 6, 1900, 75,000 bacteria per C. C.

For the week ending February 13, 1900, 133,500 bacteria per C. C.

For the week ending February 20, 1900, 112,500 bacteria per C. C.

82 For the week ending February 27, 1900, 53,000 bacteria per C. C.

For the week ending March 6, 1900, 177,000 bacteria per C. C.

For the week ending March 13, 1900, 200,000 bacteria per C. C.

For the week ending March 20, 1900, 200,000 bacteria per C. C.

For the week ending March 27, 1900, 118,000 bacteria per C. C.

The effect of the sewerage of Chicago upon the water supply of St. Louis is shown by the following bacterial results obtained from samples taken at the outlet chambers at the reservoir of the St. Louis water supply at Chain of Rocks. These samples were taken from the water which comes from the reservoir into the conduit which carries the water over to Baden leading into the conduit at Bissell's Point.

For the week ending February 6, 31,000 bacteria per C. C.

For the week ending February 13, 42,000 bacteria per C. C.

For the week ending February 20, 106,500 bacteria per C. C.

For the week ending February 27, 53,000 bacteria per C. C.

For the week ending March 6, 70,000 bacteria per C. C.

For the week ending March 13, 200,000 bacteria per C. C.

For the week ending March 20, 200,000 bacteria per C. C.

For the week ending March 27, 76,500 bacteria per C. C.

(Dr. Ravold's testimony, printed record, Volume 1, pages 355-363.)

In this connection it might be well to show from the record the comparative effect of the opening of the drainage canal on January 17, 1900, upon the waters of the Mississippi river and immediately thereafter.

This is shown by the weekly averages of the bacterial counts

in the investigation made of the waters of the respective rivers before and after the opening of the canal.

83 For week beginning January 30, or thirteen days after the opening of the canal, the average number of bacteria found in the Illinois river at Grafton was 189,500 bacterial per C. C.

The Mississippi river above Grafton, 46,000 bacteria per C. C.

Mississippi river at Alton, 115,000 bacteria per C. C.

Illinois shore, Chain of Rocks, 76,000 bacteria per C. C.

For the week beginning February 6th:

Illinois river, 257,600 bacteria per C. C.

Mississippi river above Grafton, 43,000 bacteria per C. C.

Mississippi river at Alton, 100,000 bacteria per C. C.

Missouri river at Fort Bellefontaine, 63,000 bacteria per C. C.

Mississippi river at Missouri shore, Chain of Rocks, 58,000 bacteria per C. C.

Mississippi river, Illinois shore, Chain of Rocks, 106,000 bacteria per C. C.

Mississippi river, Intake Tower, 75,000 bacteria per C. C.

For the week beginning February 20th:

Illinois river at Grafton, 221,800 bacteria per C. C.

Mississippi river at Grafton, 105,000 bacteria per C. C.

Missouri river at Fort Bellefontaine, 70,000 bacteria per C. C.

Mississippi river, Chain of Rocks, 300 feet from Missouri shore, 77,000 bacteria per C. C.

Mississippi river, 300 feet from Illinois shore, 192,000 bacteria per C. C.

Mississippi river at Intake, Chain of Rocks, 112,000 bacteria per C. C.

For the week beginning February 27th:

Illinois river at Grafton, 223,100 bacteria per C. C.

Mississippi river above Grafton, 55,000 bacteria per C. C.

Mississippi river at Alton, 156,500 bacteria per C. C.

Missouri river at Fort Bellefontaine, 63,000 bacteria per C. C.

Mississippi river, Missouri shore, Chain of Rocks, 50,500 bacteria per C. C.

84 Mississippi river, Chain of Rocks, Illinois shore, 77,000 bacteria per C. C.

Mississippi river, Intake Tower, 53,000 bacteria per C. C.

(Dr. Ravold's testimony, printed record, Volume 1, pages 366-367.)

For further showing as to the effect of the sewerage of Chicago upon the waters of the Mississippi river at the Chain of Rocks, we call attention to the following comparison. These comparisons also show a complete mixing of the water of the three rivers, Mississippi, Missouri and Illinois, at the Intake Tower, St. Louis. This is obtained by making a comparison of the bacterial count of the water of the Mississippi river above Grafton, the Illinois river at Grafton and the Missouri river at Fort Bellefontaine, and the Mississippi river, Chain of Rocks, Intake Tower.

For week beginning February 6, 1900:

Illinois river at Grafton, 109,000 bacteria per C. C.

Mississippi river above Grafton, 46,000 bacteria per C. C.

Mississippi river at Alton, 400,500 bacteria per C. C.

Mississippi river at Hartford, 106,500 bacteria per C. C.

Mississippi river at Intake Tower, St. Louis, 75,000 bacteria per C. C.

Missouri river at Fort Bellefontaine, 62,000 bacteria per C. C.

It will be observed from the foregoing table that the Mississippi river above Grafton contains 63,000 less bacteria per C. C. than the Illinois river at Grafton, and the Mississippi river at Alton contains 54,500 more bacteria per C. C. than it did above Grafton, and that the Mississippi river at the Intake, St. Louis Waterworks, contains 29,000 more bacteria per C. C. than it did above Grafton, and that the Missouri river at Fort Bellefontaine contains 46,000 less bacteria per C. C. than the Illinois river at Grafton, and 12,000 less than the Mississippi river at the Intake.

For the week beginning February 13th:

Illinois river at Grafton, 257,600 bacteria per C. C.

85 Mississippi river above Grafton, 161,000 bacteria per C. C.

Mississippi river at Hartford, 233,100 bacteria per C. C.

Mississippi river at Intake, Chain of Rocks, 133,500 bacteria per C. C.

Missouri river at Fort Bellefontaine, 52,000 bacteria per C. C.

It will be observed from the foregoing table that the Mississippi river above Grafton contained 96,000 less bacteria per C. C. than the Illinois river at Grafton, and the Mississippi river at Hartford contained 92,100 more bacteria per C. C. than the same river did above Grafton, and that the Mississippi river at the Intake, Chain of Rocks, St. Louis Waterworks, contained 81,500 more than the Missouri river did at Fort Bellefontaine, and the Missouri river at Fort Bellefontaine contained 81,500 less bacteria per C. C. than the Mississippi river at Intake.

For the week beginning February 20:

Illinois river at Grafton 221,800 bacteria per C. C.

Mississippi river above Grafton, 105,000 bacteria per C. C.

Mississippi river at Intake, 112,000 bacteria per C. C.

Missouri river at Fort Bellefontaine, 69,500 bacteria per C. C.

It will be observed from the foregoing table that the Mississippi river above Grafton contained 116,800 less bacteria than the Illinois river did at its mouth, and the Mississippi river at the Intake contained 7,000 more bacteria than it did at Grafton, while the Missouri river at Fort Bellefontaine contained 152,300 less than the Illinois river at Grafton, and 42,500 less than the Mississippi river at the Intake of the St. Louis water supply.

For the week beginning February 27th:

Illinois river at Grafton contains 223,100 bacteria per C. C.

Mississippi river above Grafton, 55,000 bacteria per C. C.

Mississippi river at Hartford, 142,000 bacteria per C. C.

Mississippi river at the Intake, St. Louis water supply, 77,000 bacteria per C. C.

Missouri river at Fort Bellefontaine, 63,000 bacteria per C. C.

86 It will be observed from the foregoing table that the Mississippi river at Grafton contained 168,000 less bacteria than the Illinois river at Grafton, and the Mississippi river at the Intake contains 22,000 more than it did at Grafton, and the Missouri river at Fort Bellefontaine contained 14,000 less bacteria than the Mississippi river at the Intake, and 160,000 less than the Illinois river at Grafton.

(Dr. Ravold's testimony, printed record, Volume 1, pages 378-380, inc.)

In connection with the foregoing, we call attention to complainant's exhibit No. 2 and the explanation of it given by Dr. Ravold in Volume 1 of the printed record at pages 382 to 383:

"On January 23, at the Illinois shore directly across from the Intake, we find the number of bacteria reaches 240,000. The

number in the Missouri river is 105,000. The number at the Intake between these points 150,000. On January 30th, we find the number of bacteria in the Mississippi river 150,000; the number in the Intake 135,000, and the number on the Missouri shore of the Mississippi river 75,000. While we have the Intake standing between these two numbers, not quite midway, but showing more Mississippi river water coming into the Intake containing 135,000 bacteria per C. C. These figures would indicate that the water at the Intake is more Mississippi river than the Missouri river and so we go throughout the map."

This exhibit shows clearly a general mixing of the water of the Mississippi before the Intake at the Chain of Rocks is reached.

Samples of water were collected from the Mississippi river at Intake Tower, St. Louis Waterworks, between the 1st and the 15th of February, 1900, or a few days after the opening of the drainage canal.

Samples were also collected from the Illinois river at Grafton, Peoria and from the Mississippi river above Alton, Hartford on the Illinois shore, and Missouri river at Fort Bellefontaine.

Samples of water collected from Peoria were almost black, entirely different from the ordinary condition of the water.
87 The water at Grafton was as dark as that at Peoria, and the water flowing down from Alton and Hartford was black, but exhibited a mixture with the Mississippi river as it came in at Grafton, not being quite so dark. The Mississippi river was very clear, remarkably so.

The samples coming from the Missouri river at Fort Bellefontaine was as clear as the water of that river generally obtains.

The water on the Missouri shore, to the naked eye, was

about the color of that in the Missouri river, but at the Intake there was a distinct mixture of the waters of the Illinois river with the Missouri river, as shown by a comparison of the samples from the respective points. The bacteriological results at this time exhibited a remarkable condition.

In the samples of the water from the Illinois at Grafton, the number of bacteria were very high, while there was a low number in the Mississippi river above Grafton, and a still lower number in the Missouri river at Fort Bellefontaine.

The bacterial characteristic of the water also presented a complete mixing of the Illinois with the Mississippi river above the Missouri, and the Mississippi above the Missouri shows a distinct mixture.

(Printed record, Volume 1, pages 835-836.)

The defendants carried on a series of bacteriological and chemical analyses of the waters of Lake Michigan. These experiments were conducted by different analysts, to wit, Prof. Palmer, Prof. Long, Doctor Bisbee and Prof. Jordan. An examination of the tables discloses a very great difference in the analytical results obtained from samples of water collected at the same points at the same time, but examined by the different experts. These differences run from 5 to 100 per cent, and show clearly that little or no reliance can be placed upon the accuracy of the determinations made.

Especial reference is made to table No. 20 of the series of tables, 1 to 80, inclusive, made by Prof. Palmer, and table 178, of the evidence introduced by defendants and known as Defendants' Tables of Streams Examined, 1 to 196, inclusive, and said table No. 178 constituted a part of the testimony of Mr.
88 Bisbee. It will be found upon comparison that these tables, during the month of September, 1899, and the samples of

water collected by the same doctor at the same point, as companion samples, one of which was shipped to Prof. Palmer and the other to Mr. Bisbee, all of which were analyzed by Prof. Palmer, to wit, September 7th, 14th, 21st and 28th, differed materially. Mr. Bisbee analyzed three of said samples, to wit, those collected September 7th, 14th, and 21st, the samples being collected on the 6th, 13th, 20th and 27th days of September, 1899. Upon the determinations made by Prof. Palmer it was found that upon September 7th the contents disclosed 1.0 of organic nitrogen, in the sample analyzed on the 14th of September .84 of organic nitrogen, in the sample analyzed on the 27th of September 1.0 of organic nitrogen, and in the sample analyzed on the 28th of September .82 of organic nitrogen, while Mr. Bisbee, in his analyses, found that the samples analyzed by him were as follows:

September 7th, organic nitrogen	.60
September 14th, organic nitrogen	1.04
September 21st, organic nitrogen	.76

No analysis was made of the samples collected on the 27th of September. The samples above referred to were taken from the Illinois river at Kampsville. It will be observed from the comparison of these analyses that a variation is shown of 18.8 per cent, counting those made by Prof. Palmer at 100.

Referring to the total solids in suspension as determined by Prof. Palmer and compared with a like determination made by Prof. Bisbee on the 8th of November, we find a difference in suspended matter of 90 per cent. The variation in nitrates is 48 per cent, in free ammonia 3.9 per cent, albuminoid ammonia 28 per cent. What is true with reference to the questions above referred to may be said of the entire series of observations made by the respective analysts. (See Palmer's testimony, Vol. 6, pp. 5665, 5673, inclusive.)

An examination of the testimony of Prof. Jordan will also

disclose that there is a wide range of difference existing between the results obtained by him, Prof. Jordan, and Prof. Palmer.

While it is true in all chemical analyses of water there is a
89 percentage of variation in the analysis, attributed to inaccuracy in the determination, this percentage of inaccuracy is stated by Prof. Palmer to be about 10 per cent, while it is said by Prof. Jordan to be about 2 per cent, yet the variations existing between the determinations made by the respective witnesses range from 5 to 100 per cent. (See Jordan's testimony, Vol. 7, pp. 6367-8-9-70.)

8

BACTERIAL CONDITION IN THE ILLINOIS RIVER HAS GROWN MORE DANGEROUS SINCE THE CANAL WAS OPENED.

According to the bacterial analyses of Prof. Jordan, the bacterial increase in the Illinois river since the opening of the canal as compared with conditions prior thereto, is as follows:

Averyville, above Peoria, increase in number of bacteria per cubic centimetre, 48,200.

Kampsville, 27,000.

Grafton, 11,000.

(See Jordan's testimony, Vol. 6, p. 5967.)

It may be well to state here from the record that various pathogenic bacteria were found in the waters of the drainage canal and the Illinois river at Morris, Henry and Havanna. The character of pathogenic bacteria so found were as follows:

Seven samples of water collected from the drainage canal disclosed the following results:

Bacteria coli communis	6
Bacteria lactis aerodenes	4
Bacteria cuteretides	2
Proteus vulgaris	6
Bacteria byocanendus	2

At Morris the samples were collected with the following results:

Bacilli coli communis,
Proteus vulgaris
Proteus mirabilis,
Bacteria tetana, or tetanus.

90 At Henry five samples were collected with the following results:

Bacteria coli communis,
Proteus vulgaris,
Bacteria tetana, or tetanus,
Staphyloculus.

At Havanna twelve samples were collected with the following results:

Bacteria coli communis,
Bacteria lactis aerodenes,
Proteus mirabilis,
Bacteria anthracis, or anthrax.
(Zeit's testimony, Vol. 5, p. 4406.)

The above determinations were made in the year 1900, subsequent to the opening of the drainage canal.

These discoveries were obtained from a small number of samples collected where the water was examined for the purpose of determining the character of the bacteria found, regardless of the quantity, and it is remarkable to note that so many pathogenic bacteria should be found in the few samples determined. More striking is this when you take into consideration the fact that bacteriologists have been using every possible means to discover some way by which pathogenic bacteria might be readily determined in the water. So far as typhoid fever germs are concerned, it is practically a matter of waste of time to undertake such determinations. According to Prof. Zeit, the determinations are so intricate and delicate that bacteriologists have abandoned the idea of making such discovery. So that so far as bacteriology is concerned the fact that pathogenic bacteria are not found in water constitutes no reason to conclude that such bacteria are not contained in it. The science

of chemistry also fails to disclose the true condition of the water from the scientific sanitary standpoint. Water may be pronounced safe by chemists and yet contain disease producing organisms, so that so far as the science of chemistry and bacteriology alone are concerned, no accurate conclusions can be arrived at, and no correct determinations made which will
91 enable one to determine accurately the sanitary condition of the water. (Long's cross-examination, Vol. 5, p. 4333; Zeit's cross-examination, Vol. 5, p. 4427; Palmer's cross-examination, Vol. 6, p. 5653.)

Chemistry, however, does disclose a certain residue in water, but does not disclose the character of such residue. (Palmer's testimony, Vol. 6, pp. 5655-6-8.)

9

CHEMICAL CONSTITUENTS OF THE WATER SHOWING INCREASE POLLUTION OF THE ILLINOIS RIVER SINCE THE OPENING OF THE CHICAGO DRAINAGE CANAL.

In the examination of water supplies for the purpose of determining their fitness for domestic use, the science of chemistry has heretofore been applied as an aid towards such determination. Chemists are frequently called upon by individuals or water companies to pass judgment upon the character of water for drinking and domestic purposes. Before such judgment is expressed it becomes necessary for them to make an analysis of the water with a view of determining as near as possible the relative proportions of chemical constituents contained therein, which from long experience and study are looked upon as evidence of sewage pollution. These constituents found in the water are, of course, not sufficient to enable the chemist to express an accurate opinion, unless he is acquainted somewhat with the local history of the water and physical conditions affecting its source, its flow and the place of its retention.

In this connection it will be well to bear in mind the extent of the area of drainage basis of the respective rivers, the Missouri, the Mississippi above Grafton and the Illinois. The watershed of the Missouri river consists of a much greater area of territory, and is less thickly populated than either the Mississippi or the Illinois rivers. While the Mississippi river watershed is more extensive than that of the Illinois river, and the population situated thereon much less than that of the Illinois, while the Illinois watershed, exclusive of the city of Chicago and the
92 Sanitary District of Chicago, is much less in area and more

thickly populated than either of the other two. By adding to this the population of the city of Chicago and of the Sanitary District, amounting to about 2,000,000, more than doubles the sewage discharged annually into the Illinois river. So that from the surrounding facts it is natural to believe and suspect that the waters of the Illinois river are more highly contaminated with sewage than either of the three rivers, and more particularly is this true when we take into consideration the fact that the volume of water passing down the Illinois is much less than that found in either the Mississippi or the Missouri, and as to population per square mile of territory it is much greater. These facts carried along with the results obtained from the chemical analysis of the respective waters are sufficient when properly considered to enable one to determine the relative values of the respective waters.

In making the determination in the analysis of water, it became the purpose of the chemists to ascertain the following chemical constituents:

First—Total solid matter.

Second—The amount of free ammonia.

Third—The amount of albuminoid ammonia.

Fourth—Total ammonia.

Fifth—The oxygen consuming the properties of the water.

Sixth—The nitrogen present as nitrates.

Seventh—The nitrogen present as nitrites.

Eighth—The chlorine.

(Keiser's testimony, printed record, Volume 1, page 975.)

It might be well here to refer specifically to Professor Keiser's statement as to those chemical constituents classed as nitrogen and usually coming from decomposed nitrogenous matter. The chemist looks upon nitrogen as an element that is characteristic of living things. Nitrogen goes through a cycle

of changes in living matter, and the presence of nitrogen compounds in water shows that the water has become contaminated with matter of vegetable or animal origin; so that the chemist attaches very great importance to the detection of nitrogen
93 in its various forms in natural water. A pure water is free from all nitrogen compounds, but such water is never found in nature. All natural waters, contain varying amounts of nitrogen in some form. The chemist looks for nitrogen in four forms: First, as free ammonia; second, as albuminoid ammonia; third, as nitrites, and, lastly, as nitrates. It might be said that the cycle of changes through which nitrogen goes is something like this: Vegetable matter requires nitrates for its growth and development. The roots of plants take up nitrates from the soil or from water, and the plant builds up complex nitrogenous compounds or albuminoids, such substances as gluten of wheat and similar albuminous substances. These albuminous substances are the foods of animals, and animals live upon these albuminous substances. And in their life processes they break down the complex nitrogenous compounds that plants have built up, to simpler compounds which are not albuminoids, and these products that are eliminated from animal bodies find their way into water and are broken down still further by still lower forms of life, by bacteria. They break down these products eliminated from animal bodies, into still simpler forms of nitrogenous compounds, namely, ammonia and nitrites, and by still further action of bacteria the ammonia and nitrites are brought back again into the nitrates. And then it is in the condition for plants to again absorb it and take it and build up the complex nitrogenous compounds which serve as food for animals. So that nitrogen is going through a cycle of changes. It is being built up into complex compounds, and animals live upon these substances and break them down partially, and then

they are finally reduced to the nitrates by means of organisms in the soil and water. This is what we call the nitrogen cycle.

(Prof. Keiser's testimony, printed record, Volume 1, pages 975-976.)

Chemists attach great importance to the detection of nitrogen compounds in water. When there found it is evident that there is nitrogenous organic matter undergoing putrefaction. It is searched for in the form of free ammonia, albuminoid, ammonia, nitrites and nitrates.

(Prof. Keiser's testimony, printed record, Volume 1, page 94 976.)

During the entire chemical investigation of the waters in question, Professor Keiser used the method recommended by the American Society for the Advancement of Science, which is regarded as the standard method, and is generally used at the present.

(Prof. Keiser's testimony, printed record, Volume 1, page 908.)

Commencing on the 24th day of January, 1900, and ending on the 11th day of October, 1900, samples of water were daily collected for chemical observations and placed in the hands of Professor Keiser, as well as other chemists who testified in the case, for chemical analysis. These samples were collected from the following places:

In the Mississippi, Missouri and Illinois rivers:

1st. The reservoir at the Chain of Rocks.

2nd. The Wet Well, Chain of Rocks.

3rd. The Intake Tower Waterworks, Chain of Rocks.

4th. The Mississippi river at Chain of Rocks, 300 feet from Missouri shore.

5th. The Mississippi river, Chain of Rocks, 300 feet from Illinois shore.

6th. In Missouri river at Fort Bellefontaine.

7th. The Mississippi river at Hartford.

8th. The Mississippi river at Alton.

9th. The Mississippi river three miles above Grafton.

10th. In the Illinois river three miles above Grafton.

11th. The Illinois river two miles above Peoria near Averyville.

12th. The Des Plaines and Chicago Drainage Canal at Lockport and Joliet.

Also in running water in the chemical laboratory of Washington University and the City Chemist's office in the old City Hall, St. Louis; drawn from the tap.

(Prof. Keiser's testimony, printed record, Volume 1, page 95 981.)

The presence of nitrites and free ammonia, together with chlorine, are regarded of chief importance, for the reason that the presence of measurable quantity of nitrites in drinking water is often regarded as a sure sign of contamination, and a chemist finding a measurable quantity of nitrites in water would condemn it as unsafe for drinking purposes. And so free ammonia, likewise, is of great importance in judging of the sanitary condition of the water for the reason that the first product produced by bacteria in decomposing sewage is free ammonia. A large quantity of free ammonia in sewage is universally found so that the chemist lays special stress on these two constituents: nitrites and free ammonia.

(Prof. Keiser's testimony, printed record, Volume 1, page 982.)

Free ammonia may be said to be ammonium carbonate, or ammonium chloride existing in the water, and has been formed by the action of bacteria upon nitrogenous organic matter. It is absent from pure water, consequently is looked upon by scientists as an evidence of contamination with nitrogenous organic matter.

(Prof. Keiser's testimony, printed record, Volume 1, page 983.)

The appearance of these constituents in water is proof that the water itself is not able to take care of the contamination or polluted matter discharged into it, which is undergoing putrefaction and decay. Their presence indicate that there is decaying vegetable or animal matter in the water, and for that reason these two chemical constituents constitute a warning to the chemists that the water should be looked upon with suspicion.

(Prof. Keiser's testimony, printed record, Volume 1, page 983.)

The testimony in the case shows that the Illinois and Mis-
96 sissippi river watersheds are free from salt beds, therefore the chlorine found in these waters must have been obtained from artificial discharges or from the sewage of the cities situated thereupon and from the waste of industrial plants. While upon the Missouri river watershed are situated large bodies of salt, and especially is one of its principal tributaries, the Kaw, known to contain large quantities of chlorine coming from the salt beds of Kansas. So that from the chemist's standpoint, if it be discovered that free ammonia, nitrites and chlorine are high, the water will be condemned as sewage polluted. This applies to the Mississippi and the Illinois river water. The chemical analysis of the waters of the Missouri river will show, however, that while the ammonia is high and chlorine high, the nitrites

are exceedingly low, therefore indicating that whatever contamination there may be in the waters of the Missouri river, it comes from a vegetable and not from an animal origin. The analysis shows further that the chlorine in the upper Mississippi river, together with the free ammonia and nitrites, are comparatively low. While in the Illinois river during the periods of investigation the free ammonia, nitrites and chlorine are exceedingly high. This is particularly true with reference to the water in this river subsequent to the opening of the canal. The testimony shows that before the opening of the canal the water was practically in the same condition chemically as that in the Mississippi.

In this connection, we call attention to the weekly and monthly averages of the various chemical constituents heretofore named contained in the respective waters, and ascertained by Professor Keiser in his determinations.

Reservoir water in St. Louis Water Works from January 24th, 1900, to October 11th, 1900:

Nitrites, parts per million.

(Jan. 24th-31st,	.0044)	Before Canal opened.)
Feb. 1-7th,	.0074)	
Feb. 7-14th,	.0080)	Average February, .0133.
Feb. 14-21st,	.0140)	
97 Feb. 21-28th,	.0240)	
Mar. 1-7th,	.0100)	
Mar. 7-14th,	.0080)	Average March, .0107.
Mar. 14-21st,	.0120)	
Mar. 21-31st,	.0130)	

Apr. 1-7	.0140)	
Apr. 7-14	.0170)	Average April, .0180.
Apr. 14-21	.0260)	
Apr. 21-30	.0140)	
May 1-7	.0097)	
May 7-14	.0046)	Average May, .0055.
May 14-21	.0049)	
May 21-31	.0031)	
June 1-7	.0040)	
June 7-14	.0039)	Average June, .0032.
June 14-21	.0027)	
June 21-30	.0020)	
July 1-7	.0017)	
July 7-14	.0013)	Average July, .0017.
July 14-21	.0021)	
July 21-31	.0017)	
Aug. 1-7	.0004)	
Aug. 7-14	.0018)	Average August, .0021.
Aug. 14-21	.0035)	
Aug. 21-31	.0025)	
Sept. 1-7	.0015)	
Sept. 7-14	.0011)	Average September, .0013.
Sept. 14-21	.0016)	
Sept. 21-30	.0010)	
Oct. 1-10	.0021)	Average October, .0021.

98 (Prof. Keiser's testimony, printed record, Volume 1, pages 984-985.)

Weekly and monthly average of free ammonia in reservoir, St. Louis WaterWorks:

	Parts per million.	
Jan. 24-31	.1112)	January average .1112.
Feb. 1-7	.2265)	
Feb. 7-14	.2345)	February average .2098.
Feb. 14-21	.1689)	
Feb. 21-28	.2094)	
Mar 1-7	.1357)	
Mar. 7-14	.1643)	March average .1890.
Mar. 14-21	.1980)	
Mar. 21-31	.2848)	
Apr. 1-7	.2690)	
Apr. 7-14	.2234)	April average .1664.
Apr. 14-21	.1030)	
Apr. 21-30	.0703)	
May 1-7	.0417)	
May 7-14	.0254)	May average .0377.
May 14-21	.0345)	
May 21-31	.0491)	
June 1-7	.0234)	
June 7-14	.0066)	June average .0130.
June 14-21	.0100)	
June 21-30	.0120)	
July 1-7	.0117)	
July 7-14	.0228)	July average .0199.
July 14-21	.0265)	
July 21-31	.0186)	

99 Aug. 1-7	.0320)	
Aug. 7-14	.0220)	August average .0276.
Aug. 14-21	.0223)	
Aug. 21-31	.0343)	
Sept. 1-7	.0208)	
Sept. 7-14	.0348)	September average .0250.
Sept. 14-21	.0263)	
Sept. 21-30	.0283)	
Oct. 1-10	.0316)	October average .0316.

(Prof. Keiser's testimony, printed record, Volume 1, pages 992-993.)

Nitrites contained in water from reservoir of St. Louis Water Works:

	Parts per million.	
Jan. 24-31	.50)	January average .50.
Feb. 1-7	.52)	
Feb. 7-14	.49)	Average for February .59.
Feb. 14-21	.57)	
Feb. 21-28	.78)	
Mar. 1-7	.61)	
Mar. 7-14	.91)	Average for March .77.
Mar. 14-21	.89)	
Mar. 21-31	.67)	
Apr. 1-7	.51)	
Apr. 7-14	.67)	Average for April .56.
Apr. 14-21	.53)	
Apr. 21-30	.54)	

May 1-7	.51)	
May 7-14	.38)	Average for May .39.
May 14-21	.32)	
May 21-31	.35)	
June 1-7	.39)	
June 7-14	.37)	Average for June .41.
June 14-21	.43)	
June 21-30	.43)	
July 1-7	.51)	
July 7-14	.49)	Average for July .46.
July 14-21	.34)	
July 21-31	.51)	
Aug. 1-7	.48)	
Aug. 7-14	.27)	Average for August .35.
Aug. 14-21	.22)	
Aug. 21-31	.42)	
Sept. 1-7	.39)	
Sept. 7-14	.36)	Average for September .37.
Sept. 14-21	.36)	
Sept. 21-30	.38)	
Oct. 1-10	.53)	Average for October .53.

(Prof. Keiser's testimony, printed record, Volume 1, pages 999-1000.)

(See also Complainant's exhibit No. 25.)

Albuminoid ammonia in the water of the Reservoir, St. Louis water supply. Table of averages from daily analysis between January 24th and October 10th, 1900:

Jan. 24-31	.214)	Average for January, .214.

Feb. 1-7	.199)	
Feb. 7-14	.285)	Average for February, .271.
Feb. 14-21	.259)	
Feb. 21-28	.344)	
Mar. 1-7	.233)	
Mar. 7-14	.325)	Average for March, .410.
Mar. 14-21	.582)	
Mar. 21-31	.501)	
Apr. 1-7	.264)	
101 Apr. 7-14	.387)	Average for April, .313.
Apr. 14-21	.248)	
Apr. 21-30	.352)	
May 1-7	.279)	
May 7-14	.285)	Average for May, .261.
May 14-21	.224)	
May 21-31	.257)	
June 1-7	.155)	
June 7-14	.172)	Average for June, .182.
June 14-21	.161)	
June 21-30	.240)	
July 1-7	.219)	
July 7-14	.192)	Average for July, .234.
July 14-21	.249)	
July 21-31	.275)	
Aug. 1-7	.304)	
Aug. 7-14	.233)	Average for August, .257.
Aug. 14-21	.202)	
Aug. 21-31	.289)	

Sept. 1-7	.276)	
Sept. 7-14	.238)	Average for Septe'ber, .237
Sept. 14-21	.225)	
Sept. 21-30	.210)	
Oct. 1-10	.335)	Average for October, .335.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1004-1005.)

We now come to a consideration of the chemical constituents contained in waters of the Mississippi river, 300 feet from the Missouri shore, and 300 feet from the Illinois shore, opposite the Intake Tower at the Chain of Rocks, during the period from January 24th to October 10th, 1900. During this time sam-
102 ples of water were collected daily and analyzed by Professor Keiser, Dr. Teichmann and others. We here give the table showing the weekly and monthly average of nitrites in parts per million at the above point, as follows:

NITRITES.

Missouri Shore.			Illinois Shore.		
Date.	Parts per million.		Parts per million.		
Jan. 24-31	.0070)	Jan. average, .0070	.0130)	Jan. average, .0130	
Feb. 1-7	.0065)		.0214)		
Feb. 7-14	.0183)	Feb. average,	.0000)	Feb. average,	
Feb. 14-21	.0123)	.0144	.0211)	.0187	
Feb. 21-28	.0206)		.0136)		
Mar. 1-7	.0140)		.0123)		
Mar. 7-14	.0128)	Mar. average,	.0080)	Mar. average,	
Mar. 14-21	.0183)	0168	.0254)	.0164	
Mar. 21-31	.0223)		.0200)		

Missouri Shore.			Illinois Shore.		
Date.	Parts per million.		Parts per million.		
Apr. 1-7	.0325		.0365)		
Apr. 7-14	.0118)	Apr. average,	.0305)	Apr. average,	
Apr. 14-21	.0080)	.0168.	.0288)	.0308.	
Apr. 21-30	.0148)		.0274)		
May 1-7	.0057)		.0157)		
May 7-14	.0028)	May average,	.0134)	May average,	
May 14-21	.0028)	.0035.	.0148)	.0154.	
May 21-31	.0023)		.0178)		
June 1-7	.0028)		.0050)		
June 7-14	.0026)	June average,	.0032)	June average,	
June 14-21	.0028)	.0026.	.0035)	.0050.	
June 21-30	.0024)		.0084)		
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July 1-7	.0015		.0041)		
July 7-14	.0017)	July average,	.0043)	July average,	
July 14-21	.0010)	.0014.	.0043)	.0041.	
July 21-31	.0014)		.0037)		
Aug. 1-7	.0001		.0037)		
Aug. 7-14	.0015)	Aug. average,	.0077)	Aug. average,	
Aug. 14-21	.0014)	.0012.	.0102)	.0063.	
Aug. 21-31	.0017)		.0038)		
Sept. 1-7	.0016)		.0070)		
Sept. 7-14	.0003)	Sept. average,	.0071)	Sept. average,	
Sept. 14-21	.0004)	.0008.	.0067)	.0068.	
Sept. 21-30	.0011)		.0067)		
Oct. 1-10	.0011)	Oct. average,	.0064)	Oct. average,	
	)	.0011.	)	.0064.	

(Professor Keiser's testimony, printed record, Volume 2, pages 1014-1015.)

FREE AMMONIA.

At the Missouri shore and Illinois shore the average parts per million of free ammonia for the period from January 24th, 1900, to October 10th, 1900, is shown by the following table, made from the results obtained by the analysis of the water taken from the Mississippi river at Intake Tower, 300 feet from the Missouri shore and the Illinois shore, respectively:

Date (1900).	Missouri Shore.		Illinois Shore.	
Jan. 24-31	.1208)	Jan. average, .1208.	.4920)	Jan. average, .4920.
Feb. 1-7	.2200)		.4670)	
Feb. 7-14	.1800)	Feb. average,	.....)	Feb. average,
Feb. 14-21	.1431)	.1673.	.4820)	.4180.
Feb. 21-28	.1260)		.3050)	
Mar. 1-7	.1048)		.3000)	
104 Mar. 7-14	.1582)	Mar. average,	.2851)	Mar. average,
Mar. 14-21	.1731)	.1457.	.3020)	.2981.
Mar. 21-31	.1468)		.3060)	

Missouri Shore.	Illinois Shore.
April average, .0609	April average, .1770
May average, . 0614	May average, .0566
June average, .0416	June average, .0267
July average, .0504	July average, .0291
Aug. average, .0322	Aug. average, .0304
Sept. average, .0454	Sept. average, .0448
Oct. average, .0508	Oct. average, .0448

(Prof. Keiser's testimony, printed record, Volume 2, pages 1021-1022.)

NITRITES.

At the above mentioned place, to wit, Chain of Rocks, samples of water were collected between the Missouri and Illinois shores. The following weekly and monthly average is for nitrites for the period from January 24th to October 10th, 1900:

Date (1900).	Missouri Shore.		Illinois Shore.	
Jan. 24-31	.565)	Jan. average, .565.	1.040)	Jan. average, 1.040.
Feb. 1-7	.457)		.765)	
Feb. 7-14	.457)	Feb. average,	....)	Feb. average,
Feb. 14-21	.542)	.485.	.882)	.790.
Feb. 21-28	....)		....)	
Mar. 1-7	.688)		1.205)	
Mar. 7-14	1.343)	Mar. average,	.822)	Mar. average,
Mar. 14-21	.954)	.935.	1.001)	1.004.
Mar. 21-31	.754)		.980)	
Apr. 1-7	.577)		.977)	
Apr. 7-14	.462)	Apr. average,	1.022)	Apr. average,
Apr. 14-21	.434)	.478.	.897)	.936.
Apr. 21-30	.497)		.851)	
May 1-7	.594)		.600)	
May 7-14	.451)	May average,	.331)	May average,
May 14-21	.371)	.455.	.394)	.435.
May 21-31	.405)		.497)	
June 1-7	.325)		.422)	
June 7-14	.285)	June average,	.388)	June average,
June 14-21	.371)	.364.	.434)	.435.
June 21-30	.474)		.494)	

Date (1900).	Missouri Shore.		Illinois Shore.	
July 1-7	.423)		.508)	
July 7-14	.423)	July average,	.514)	July average,
July 14-21	.434)	.483.	.514)	.581.
July 21-31	.651)		.788)	
Aug. 1-7	.491)		.514)	
Aug. 7-14	.251)	Aug. average,	.234)	Aug. average,
Aug. 14-21	.314)	.345.	.304)	.419.
Aug. 21-31	.325)		.622)	
Sept. 1-7	.268)		.485)	
Sept. 7-14	.320)	Sept. average,	.505)	Sept. average,
Sept. 14-21	.365)	.358.	.428)	.433.
Sept. 21-30	.480)		.313)	
Oct. 1-10	.617)	Oct. average,	.388)	Oct. average,
	....)	.617.	....)	.388.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1026-1027.)

In the Missouri river at Fort Bellefontaine during the period from January 24th, 1900, to October 10th, 1900, the following results were obtained from chemical analysis of the water of the Missouri at Fort Bellefontaine. Fort Bellefontaine being situated upon the Missouri river about eight miles above its mouth:

106 CHLORINE.

The monthly averages of chlorine in the waters of the river at Fort Bellefontaine runs as follows:

The average for	January, 1900, was	23.5
"	February	18.6
"	March	12.1

The average for	April	12.5
"	May	14.5
"	June	11.4
"	July	11.2
"	August	12.8
"	September	16.3
"	October	11.4

(Prof. Keiser's cross-examination, printed record, Volume 2, pages 1104-1105.)

NITRITES.

The average nitrites for the same months is as follows:

The average for 1900 was

January	.008
February	.014
March	.023
April	.018
May	.013
June	.003
July	.001
August	.001
September	.002
October	.002

(Prof. Keiser's cross-examination, printed record, Volume 2, page 1105.)

NITRATES.

The average is as follows:

January	.415
February	.592
March	.965

107	April	.485
	May	.484
	June	.418
	July	.462
	August	.435
	September	.381
	October	.560

(Prof. Keiser's cross-examination, printed record, Volume 2, page 1105.)

FREE AMMONIA.

The average is as follows:

January	.135
February	.232
March	.144
April	.069
May	.083
June	.067
July	.055
August	.038
September	.068
October	.055

(Prof. Keiser's cross-examination, printed record, Volume 2, page 1105.)

ALBUMINOID AMMONIA.

The average is as follows:

January	.363
February	.395
March	1.182
April	.775

	May	1.484
	June	1.181
	July	1.556
	August	.842
108	September	1.133
	October	1.382

(Prof. Keiser's examination, printed record, Volume 2, page 1106.)

In the Mississippi river above Grafton for the same period during the year 1900 the following general average results were obtained: Free ammonia 0.176 parts per million, nitrites 0.005, albuminoid ammonia 0.565.

The Illinois river at Grafton during the same period in the year 1900, disclosed, upon examination, the following chemical constituents:

FREE AMMONIA.

January	1.498
February	.946
March	.322
April	.113
May	.1079
June	.0321
July	.0443
August	.406
September	.0517
October	.0677

NITRITES.

January	.0300
February	.0245

	March	.0170
	April	.037
	May	.0459
	June	.193
	July	.0352
	August	.239
	September	.0257
109	October	.0428

FREE AMMONIA.

Average for the period	.0176

ALBUMINOID AMMONIA.

Average for the period	.565

CHLORINE.

Average for the period, parts per million:

January	5.7
February	6.1
March	4.5
April	4.8
May	4.2
June	5.1
July	7.7
August	5.2
September	3.3
October	3.9

(Prof. Keiser's examination, printed record, Volume 2, pages 1053-1077.)

In the Illinois river above Grafton for the 1900 period, the following results were obtained by Professor Keiser in his analyses:

NITRITES.

	January	.0300
	February	.0245
	March	.0170
	April	.370
	May	.0459
	June	.193
110	July	.352
	August	.239
	September	.0257
	October	.0428

FREE AMMONIA.

	January	1.498
	February	.946
	March	.322
	April	.113
	May	.1079
	June	.0321
	July	.0443
	August	.0406
	September	.0517
	October	.0677

(Prof. Keiser's examination, printed record, Volume 2, page 1047.)

CHLORINE.

	January	14.1
	February	13.1
	March	7
	April	6.1
	May	10.9

June	12.6
July	18
August	16.5
September	14.8

(Prof. Keiser's examination, printed record, volume 2, page 1053.)

During this period the average albuminoid ammonia at the place above mentioned was .0193.

(Prof. Keiser's examination, printed record, volume 2, page 1075.)

111 The following results from the analyses of the water in the Illinois river at Joliet for the 1900 period is as follows:

NITRITES.

March	.0558
April	.0663
May	.0256
June	.0326
July	.0551
August	.0465
September	.0524
October	.0562
March	2.689
April	2.732
May	2.995
June	3.270
July	3.701
August	2.933
September	4.498
October	3.306

(Prof. Keiser's examination, printed record, volume 2, page 1056.)

Drainage Canal at Lockport for the 1900 period disclosed the following general average results:

NITRITES.

March	.0603
April	.0730
May	.0234
June	.0114
July	.0081
August	.0083
September	.0073
October	.0138

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FREE AMMONIA.

March	2.437
April	1.806
May	1.598
June	1.411
July	1.631
August	1.589
Sptember	2.195
October	1.555

Illinois river above Peoria during the same period disclosed the following results:

NITRITES.

February	.0358
March	.0209
April	.0467
May	.0752

June	.1317
July	.1657
August	.1597
September	.1382
October	.1857

FREE AMMONIA.

February	1.416
March	.685
April	.392
May	.266
June	.228
July	.230
August	.142
September	.255
October	1.404

(Prof. Keiser's testimony, printed record, volume 2, pages 1057-1058-1059-1060.)

113 Prior to the opening of the Canal, during the latter part of the year 1899 and the first few days in January, 1900, the following results were obtained from the analyses of water taken from the respective points, which exhibit a complete change in the chemical condition of the Mississippi river at the Chain of Rocks immediately after the Drainage Canal was opened, and which continued throughout the entire years of 1900 and 1901.

The water taken from the reservoir, St. Louis Waterworks, discloses the following average for the period examined, immediately before the opening of the canal:

Free Ammonia	0.013
Nitrites	0.004
Albuminoid Ammonia	0.214

The Mississippi river at Alton during the period immediately prior to the opening of the canal discloses the following general average results:

Free Ammonia	0.288
Nitrites	0.104
Albuminoid Ammonia	0.200

(Prof. Keiser's testimony, printed record, volume 2, page 1074.)

Missouri river at Fort Bellefontaine, 14 miles from the Chain of Rocks, disclosed the following general average results:

Free Ammonia	0.114
Nitrites	0.013
Albuminoid Ammonia	0.063

(Prof. Keiser's testimony, printed record, volume 2, pages 1077-1078.)

Illinois river at Grafton before the opening of the Drainage Canal discloses the following general average results:

Free Ammonia	0.113
Nitrites	0.005
Albuminoid Ammonia	0.478

(Prof. Keiser's testimony, printed record, volume 2, page 1075.)

114 The Illinois river at Peoria before the Drainage Canal was opened discloses the following results:

Free Ammonia	0.895
Nitrites	0.141
Albuminoid Ammonia	0.572

(Prof. Keiser's testimony, printed record, volume 2, page 1076.)

During the months of October and November, 1901, the following weekly averages of nitrites were obtained from water taken from Intake Tower, St. Louis Waterworks:

	Parts per Million.
Oct. 1-7	.0037
" 7-14	.0029
" 14-21	.0050
" 21-28	.0048
Oct. 28-Nov. 4	.0131
Nov. 4-11	.0131
" 11-18	.0143
" 18-25	.0130
" 25-30	.0116

(Prof. Keiser's testimony, printed record, volume 1, page 990.)

During the same months, to wit, October and November, 1901, free ammonia contained in the waters of the Intake Tower was in weekly average as follows:

Oct. 1-7 Inc.	.129
" 7-14 Inc.	.051
" 14-21 Inc.	.046
" 28-Nov. 4	.071
Nov. 4-11	.070
" 11-18	.086
" 18-25	.072
" 25-30	.071

(Prof. Keiser's testimony, printed record, volume 1, page 998.)

115 For the same period, the same water disclosed the following weekly averages of nitrates, expressed in parts per million:

Oct. 1-7	.60
" 7-14	.29
" 14-21	.21
" 21-28	.43
" 28-Nov. 4	.38
Nov. 4-11	.27
" 11-18	.25
" 18-25	.12
" 25-30	.12

(Prof. Keiser's testimony, printed record, volume 1, page 1001.)

In Albuminoid Ammonia the following results were obtained for the same period:

Oct. 1-7 incl.	.855
" 7-14 incl.	.677
" 14-21 incl.	.523
" 21-28 incl.	.727
" 28-Nov. 4	.553
Nov. 4-11	.493
" 11-18	.794
" 18-25	.536
" 25-30	.420

(Prof. Keiser's testimony, printed record, volume 2, page 1007.)

During the same period the water in the Mississippi river, 300 feet from the Missouri shore, disclosed the following results in nitrites, expressed in parts per million:

NITRITES.

Date (1901)	Missouri Shore. Parts per Million	Illinois Shore. Parts per Million
Oct. 1-7	.0024	.0110
" 7-14	.0027	.0124
116 " 14-21	.0057	.0144
" 21-28	.0048	.0160
" 28-Nov. 4	.0082	.0123
Nov. 4-11	.0124	.0167
" 11-28	.0141	.0177
" 18-25	.0096	.0171
" 25-30	.0128	.0170

(Prof. Keiser's testimony, printed record, volume 2, page 1018.)

The average quantity of free ammonia found on each side of the Mississippi river in the Intake in October and November, 1901, is as follows:

1901	Missouri Shore	Illinois Shore
Oct. 1-7	.0805	.0869
" 7-14	.0520	.0571
" 14-21	.0449	.0706
" 21-28	.0449	.0557
" 28-Nov. 4	.0717	.0957
Nov. 4-11	.0634	.0714
" 11-28	.0894	.0720
" 18-25	.0810	.0489
" 25-30	.0844	.0648

(Prof. Keiser's testimony, printed record, volume 2, pages 1025-1026.)

NITRATES.

1901	Missouri Shore	Illinois Shore
Oct. 1-7	.428	.485
" 7-14	.428	.291
" 14-21	.240	.269
" 21-28	.377	.331
" 28-Nov. 4	.400	.360
Nov. 4-11	.234	.497
" 11-18	.257	.257
117 " 18-25	.260	.291
" 25-30	.184	.223

(Prof. Keiser's testimony, printed record, volume 2, page 1030.)

The weekly average of nitrates in water of the Mississippi river, Chain of Rocks, Illinois Shore at Hartford and Alton, during the months of October and November, 1900:

	Illinois shore.		
Date.	Chain of Rocks.	Hartford.	Alton.
October 1 to 7.....	.0110	.0235	.0160
October 7 to 14.....	.0124	.0184	.0121
October 14 to 21.....	.0144	.0150	.0180
October 21 to 28.....	.0160	.0163	.0190
October 28 to November 4...	.0123	.0137	.0102
November 4 to 11.....	.0167	.0191	.0103
November 11 to 16.....	.0177	.0190	.0124
November 18 to 25.....	.0171	.0167	.0072
November 25 to 30.....	.0170	.0186	.0088

(Prof. Keiser's testimony, printed record, volume 2, page 1040.)

Samples of water taken from the Chicago Drainage Canal, extending from October 9th to November 30, 1901, disclosed the following chemical constituents:

NITRITES.

	October	9th	Nitrites	.016
	"	10th	"	.040
	"	11th	"	.018
	"	12th	"	.017
	"	13th	"	.036
	"	14th	"	.015
	"	15th	"	.017
	"	16th	"	.018
	"	17th	"	.018
	"	21st	"	.019
118	"	22nd	"	.027
	"	23rd	"	.013
	"	24th	"	.016
	"	26th	"	.015
	"	27th	"	.014
	"	28th	"	.025
	"	29th	"	.016
	"	30th	"	.019
	"	31st	"	.018

November 1, 1901, Nitrites parts per million.

	November	1st	Nitrites	.028
	"	2nd	"	.016
	"	3rd	"	.017
	"	4th	"	.013
	"	5th	"	.017
	"	6th	"	.015

November	7th	Nitrites	.018
"	8th	"	.028
"	9th	"	.015
"	10th	"	.015
"	11th	"	.013
"	12th	"	.025
"	13th	"	.015
"	14th	"	.015
"	15th	"	.027
"	16th	"	.016
"	17th	"	.023
"	18th	"	.015
"	19th	"	.016
"	21st	"	.007
"	22nd	"	.013
"	23rd	"	.018
"	24th	"	.017
"	26th	"	.017
"	27th	"	.017
"	28th	"	.016
119 "	29th	"	.017
"	30th	"	.015

(Prof. Keiser's testimony, printed record, volume 2, pages 1060-1061.)

CHLORINE.

October	9th	Chlorine	22.8
"	10th	"	23.0
"	11th	"	18.0
"	12th	"	12.1
"	13th	"	20.8
"	14th	"	21.0

October	15th	"	19.0
"	16th	"	23.2
"	17th	"	19.5
"	21st	"	22.3
"	22nd	"	22.5
"	23rd	"	17.5
"	24th	"	18.2
"	26th	"	22.0
"	27th	"	21.3
"	28th	"	21.7
"	29th	"	23.8
"	30th	"	29.0
"	31st	"	24.2
November	1st	"	21.5
"	2nd	"	23.0
"	3rd	"	13.8
"	4th	"	13.2
"	5th	"	11.3
"	6th	"	10.0
"	7th	"	16.0
"	8th	"	12.0
"	9th	"	10.8
"	10th	"	14.2
"	11th	"	14.8
"	12th	"	10.6
"	13th	"	12.2
"	14th	"	9.0
"	15th	"	8.0
"	16th	"	11.0
"	17th	"	11.0
"	18th	"	9.0
"	19th	"	11.2

November	21st	"	8.0
"	22nd	"	11.9
"	23rd	"	11.3
"	24th	"	12.3
"	26th	"	9.0
"	27th	"	11.6
"	28th	"	16.1
"	29th	"	16.2
"	30th	"	29.0

(Prof. Keiser's testimony, printed record, volume 2, pages 1062-1063.)

FREE AMMONIA.

October	9th	Free Ammonia	.328
"	10th	"	2.860
"	11th	"	.676
"	12th	"	.812
"	13th	"	1.66
"	15th	"	1.072
"	16th	"	1.500
"	17th	"	.884
"	21st	"	.672
"	22nd	"	.334
"	23rd	"	.884
"	24th	"	.796
"	26th	"	.732
"	27th	"	1.020
"	28th	"	1.288
"	29th	"	.744
"	30th	"	.700
"	31st	"	.744

121

November	1st	Free Ammonia	.968
"	2nd	"	.628
"	3rd	"	.648
"	4th	"	.988
"	5th	"	1.068
"	6th	"	.568
"	7th	"	.652
"	8th	"	.436
"	9th	"	.452
"	10th	"	.849
"	11th	"	.560
"	12th	"	5.192
"	13th	"	.568
"	14th	"	.640
"	15th	"	.468
"	16th	"	.428
"	17th	"	.588
"	18th	"	.452
"	19th	"	.560
"	21st	"	.716
"	22nd	"	.564
"	23rd	"	.504
"	24th	"	.628
"	26th	"	.404
"	27th	"	.968
"	28th	"	.256
"	29th	"	1.892
"	30th	"	2.140

(Prof. Keiser's testimony, printed record, volume 2, pages 1063-1064.)

The chemical analyses made by Professor Keiser disclosed that early in February, 1900, quantities of nitrites in the water of the St. Louis Reservoir began to increase materially, and was, from that date on, in a very high polluted condition. This abnormal increase in nitrites is attributed to large quantities of sewage coming down the Mississippi river, and from the 122 analysis made at other points along the Mississippi and Illinois rivers it will be observed that this sewage came down the Illinois river from Chicago.

(Prof. Keiser's testimony, Volume 1, pages 988-989 and 997.)

The chemical analyses made by Professor Keiser shows clearly that for the period beginning January 24, 1900, to October 10, 1900, and from thence on, the water in the Mississippi river, at Chain of Rocks, became suddenly badly polluted about the first week, and has since so continued to be polluted. This is shown by the large increase in quantity of free ammonia and nitrites in the reservoir water throughout the entire period traceable under the chemical observation made by Professor Keiser of the Illinois river and the Chicago Drainage Canal.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1007-1008.)

Another remarkable fact is shown by these chemical observations, to wit, that the water in the Missouri river was less contaminated with sewage pollution than the Mississippi and the Illinois rivers, and that during the entire period of the investigation larger quantities of chemical constituents were found in the Mississippi river near the Illinois shore than on the Missouri shore, and larger quantities were found near the Intake, 1,500 feet from the Missouri shore, than were found at the Missouri shore. The quantities found on the Illinois shore at the

Intake being considerable larger than those contained in the samples of water in Fort Bellefontaine.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1018-1019-1020.)

It is also apparent that the Mississippi river above the mouth of the Illinois was in much better condition than the Illinois river at its mouth or the Mississippi river below the mouth of the Illinois.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1033-1034-1035-1036.)

The sewage contamination of the Illinois river is shown to
123 have gradually increased as the stream is ascended until the Chicago Drainage Canal is reached.

(Prof. Keiser's testimony, printed record, Volume 2, page 1040.)

At Joliet and Lockport the analysis of the water shows the water to be sewage. The results for free ammonia and nitrites being such as are obtained from analyzed sewage. Before the opening of the canal the movement in the Illinois river was much slower than afterwards. In the examinations made prior to the opening of the Canal it shows that oxidation had proceeded much further, and after the opening of the Drainage Canal the quantity of nitrites increased enormously, and kept on increasing throughout the time the examinations were made.

The effect of the opening being to wash out the oxidation materials and carry them further down the river.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1044-1045-1046-1047.)

Professor Keiser stated in his judgment as a chemist and from his chemical examination of the waters in question, that

the pollution and contamination of the sewage of Chicago passed down the Illinois river through the Chain of Rocks, a portion of it finding its way into the Intake Tower of the St. Louis Waterworks, and thence into the reservoir. The water supply of the city of St. Louis being thereby contaminated with the sewage of Chicago, discharged into the Chicago Drainage Canal, and thence into the Des Plaines and Illinois rivers. The volume of water since the opening of the canal in the Illinois river, having been very greatly increased, produces the effect of disposing of the sewage of Chicago very rapidly by carrying and pushing it down the Illinois river. In fact, it is caused to be pushed down the Illinois river into the Mississippi river in great quantities. This increased velocity of the water has a tendency to destroy the process of sedimentation. Sedimentation, therefore, is much less in the Illinois river now than it was prior to the opening of the canal, for the reason that there is a more rapid current which carries the suspended matters along with the stream and gives less opportunities for sedimentation.

124

(Prof. Keiser's testimony, printed record, Volume 2, pages 1048-1049.)

The average results of Prof. Teichman's daily analysis for the period from January 23rd to October 11, 1900, at Lockport, from water collected, show free ammonia, 1.585 parts per million, nitrites .026 parts per million. These high results of nitrogen are followed by a corresponding rise of high results in the Illinois river three miles above Grafton during the same period, and clearly show the enormous pollution caused by the flushing out of the Chicago river and the Drainage Canal, and carrying forward into the Illinois river enormous quantities of or-

ganic matter, the conditions for self-purification being practically impossible. This fact is more particularly demonstrated by a careful observance of the chemical analyses of the water in the Illinois river throughout its entire length during the months of January and February, 1900, immediately after the opening of the Chicago Drainage Canal. It will be noticed that in January, immediately after the opening, the chlorines at Peoria increased to 28 parts per million, which is followed by an increase at Grafton from 15 to 23 parts per million. With reference to free ammonia, the same conditions obtained at Peoria and Grafton as in the case of chlorine, immediately following the opening of the canal. A corresponding increase is observed from the city of Chicago until the water reaches the Mississippi at Grafton.

(See Teichmann's testimony, Volume 2, pages 1206-7-8.)

What is said with reference to an increase in free ammonia and chlorine may also be applied to nitrites. During the period from January until October, 1900, there is a significant correspondence of the fluctuations in nitrites at the various points upon the Illinois river. During this investigation it was also discovered, as is shown by the chemical analyses, that the waters of the Illinois river were in a peculiarly unsuitable char-
125 acter as compared with the waters of the Mississippi river above Grafton, the point of entrance of the Illinois. One of the most conclusive tests of the effect of the Illinois river water upon the Mississippi river water is shown by the chlorine properties of the respective rivers, which, when considered along with the increase in free ammonia and nitrites, bear us onward to the inevitable conclusion that the increased pollution of the Mississippi river below Grafton is due to the discharge of nitrogenous animal matter into the waters. The chlorines

are observed to be much lower in the Mississippi river above Grafton than in the Illinois, and the chlorines in the Illinois prior to the opening of the Drainage Canal were much lower than since the opening. Below Grafton the Mississippi river is shown to have increased materially in chlorines, and this, too, at a point above the entrance of the Missouri, so that the large quantities of chlorines contained in the Missouri river are not to be considered as producing a material effect. Thus, considering the high chlorines in the Missouri, accompanied with low free ammonia and nitrites, we conclude that the polluting matter contained in the Missouri river is due to vegetable decomposing matter, and to salt derived from the salt beds drained by the Missouri river, rather than from animal origin. This being true, the increase in chlorines, free ammonia and nitrites in the waters of the Mississippi river at the intake, demonstrate clearly and forcibly that the increased pollution is due to the effect of the opening of the Drainage Canal upon the waters of the Illinois river.

(See Teichmann's testimony, Volume 2, pages 1209-10-1211-15-16-17-18-19-20-21-22.)

In the chemical observations of the water supply, the following conditions may be said to have been by long experience found to exist: First, high free ammonia, high nitrites and high chlorine indicate sewage pollution. The foregoing is of course conditioned upon the hypothesis that the watershed of the stream examined is populated, and that there are no salt beds of importance upon the watersheds; second, high free ammonia, high nitrites and high chlorine, with low nitrates, indicate sewage pollution in its earlier stages; third, low free
126 ammonia and low nitrites, with high chlorines indicate vegetable pollution with salt beds located upon the watershed

of the river examined; fourth, low free ammonia, low nitrites and high chlorine and high nitrates indicate that the water examined may have been sewage polluted, but has traveled sufficient distance and under such favorable circumstances as to largely reduce the organic matter, and thereby, to some extent, free the river of its polluting substances, but does not necessarily indicate that the disease producing organisms, or the pathogenic bacteria have disappeared from the water.

(See Keiser's testimony, Vol. 2, pp. 1012, 1013, 1019; also Teichmann's testimony, Vol. 2, pp. 1212, 1213, 1225, 1653, 1654, 1655, 1656, 1691; also Keiser's testimony, Vol. 2, pp. 1724-5.)

The terms nitrates, nitrites, albuminoid and free ammonia are defined by Mr. Whipple in his testimony in Vol. 3, pp. 2060 to 2063.

From the testimony above referred to, together with the chemical analyses made from samples collected from the respective waters, it will be observed, first, that the waters of the upper Mississippi river, to wit, above Grafton, contain low free ammonia, low nitrates and low chlorine, and the waters of the Missouri river also contain low free ammonia and low nitrites, with high chlorines, the nitrates and free ammonia being much lower in the Missouri river than in the upper Mississippi, while the waters of the Illinois river at its mouth contain high free ammonia, high nitrites and high chlorines, and this apparent pollution continually increases as the river is ascended until the Chicago Drainage Canal is reached, where the chemical analysis showed enormous quantities of constituents which are carried into the canal from the sewers of Chicago. This increase in pollution of the Illinois river is shown to be due to the sewers of Chicago and not from any city located upon the

natural watershed of the Illinois river or from the tributaries of that river, the analyses of the waters in the tributaries showing the condition much improved over that existing in the Illinois river itself.

10

DISAPPEARANCE OF BACTERIA IN RIVERS.

There are several reasons given by scientists for the gradual disappearance of bacteria in the water.

AERATION.

Which means adding air to the water, and it was formerly thought that the oxygen of the air was injurious to the bacteria. It is known that the oxygen in the water causes the anaerobic bacteria to cease their activity, but later experiments have shown that agitation and aeration do not kill the bacteria and consequently do not reduce the number.

DILUTION.

The investigation made in this case shows that the Des Plaines river and other rivers, as the water flows along from the Drainage Canal, are added to the total quantity of bacteria passing over the dam. This of course produces dilution. In other words, it may be demonstrated in the following way: A quart of water contained 100 bacilli, added to 99 quarts of water, which result in one bacilli to one quart of water, the dilution in this way removed the bacilli further apart so that in taking a particular sample or quantity of water from the main force, we get a less number of bacteria to a definite quantity of water.

The bacteria, however, are all there, but simply removed further apart by the quantity of water that is added to it.

EFFECT OF THE SUNLIGHT.

During the experiments made in this investigation an opportunity was given to determine to some extent the effect of the

sunlight upon the bacteria, especially bacilli typhosus.
128 There was very little difference noted in the numbers of bacteria in samples collected between bright sunshiny days and the gloomy and foggy days. The depth that the sunlight can penetrate to the injury of bacteria is not very great. It is more in clear water than in turbid waters. In summer days the action of the rays of the sun may be said to be more active than in winter days, but these determinations, however, show the sunlight has very little to do with decreasing the number of bacteria in a given quantity of water.

SEDIMENTATION.

Bacteria are particles. They have weight, not very great, but still those that can not swim are gradually carried to the bottom of the stream, and where the stream flow is not rapid, sedimentation of course becomes, to some extent, greater. This, however, does not mean that the bacteria are dead. It simply means that they have been carried to the bottom of the stream and remain in muck and slime at the bottom of the stream until carried away by refreshing or a larger body of water.

SEPTIC ACTION.

When the water becomes perfectly quiet and is permitted to stand for considerable length of time, septic action takes place, and where the stream or body of water is highly polluted the septic action has powerful effect upon the bacterial contents of the water. In fact, in a short time all bacterial growth is destroyed.

EXHAUSTION OF FOOD SUPPLY.

It has been suggested by some that the food supply of the bacteria in a body of water becomes exhausted and therefore

causes the bacteria to perish. This theory, however, as applied to pathogenic bacteria, is not considered of much importance. It may be said that dilution and sedimentation really constitute the prime factors and the real cause of bacteria in running
129 streams. In neither case can it be said that the bacteria are destroyed in dilution, they are removed further apart, while in sedimentation they remain in the bottom of the stream until taken up and carried down by an increase of the velocity of the water.

(Printed record, Volume 1, pages 809-812.)

The dilution of sewage or water contaminated by sewage removes the infected material further apart, but does not destroy it, in fact the witnesses agree that instead of destroying infectious germs it has a tendency to prolong their life.

(Sedgwick's testimony, Vol. 3, page 2217.)

11

MICROSCOPIC OBSERVATIONS OF THE WATERS OF LAKE MICHIGAN; CHICAGO DRAINAGE CANAL, AND ILLINOIS AND MISSISSIPPI RIVERS.

In October and November, 1901, Mr. Geo. C. Whipple made microscopic examinations from one hundred and thirty-six samples of water taken from Lake Michigan, Chicago Drainage Canal, from the Illinois river, from the tributaries to the Illinois river, Mississippi above Grafton, Mississippi at Alton, Mississippi at Ft. Bellefontaine and the Mississippi at the Chain of Rocks, Intake Tower, and on the Mississippi and Illinois shores near the St. Louis waterworks. Strictly speaking, microscopic organisms contained in the water are very minute particles of substance, minute forms of life, too small to be identified without the use of the microscope, but large enough to be studied without the use of artificial cultures, as in the case of bacteria. Microscopic organisms belong some to the plant kingdom and some to the animal kingdom, although among the forms it is somewhat difficult to draw the distinction between animals and plants; while bacteria are all determined as belonging to the vegetable kingdom and constitute vegetable matter. Some of the microscopic organisms might die out during the period of transit, or while contained in the water, others might pos-
130 sibly develop during transit, while others still, would probably remain unchanged; at any rate, they would not increase in number, nor would they disintegrate to such extent as to be unrecognizable. In these determinations Mr. Whipple found the organisms known as synedera pulchella, variety subprolongata to largely exist in the waters of Lake Michigan, but

not found in the waters of its tributaries or the Mississippi and Illinois rivers. This variety was also found in the waters of the Mississippi at the intake, demonstrating clearly that it passed from Lake Michigan down the Illinois river to the intake at the Chain of Rocks. Several other varieties, natural to Lake Michigan water, but not found to any considerable extent in the waters of the Mississippi above Grafton tributary to the Illinois or the Missouri, were observed in the waters collected from the Mississippi at the Chain of Rocks, demonstrating that living organisms contained in the waters of Lake Michigan passed through the canal into the river and thence into the Mississippi and the intake of the St. Louis Waterworks.

(See Whipple's testimony, Vol. 2, page 1909, and Complainant's Exhibits 46, with the sub-numbers one to fourteen, inclusive. See also, Whipple's testimony, pp. 1932, 1995-6.)

It might be well in this connection to state that Dr. Ravold, in his examination of the respective waters involved in this case, detected certain forms of vegetable life in the waters of the Mississippi river at the Intake and in the reservoir water of the city of St. Louis, which naturally inhabit the waters of Lake Michigan, but which are not found in the waters of the Missouri, Mississippi or the tributaries of the Illinois.

(See Ravold's testimony, Vol. 1, pp. 316 to 360, inc.)

12

PRODIGIOSUS.

The bacillus prodigiosus is a micro-organism discovered by Ehrenberg. It is a little larger than the typhoid bacillus. It is 131 non-spore forming and non-pathogenic. It is founded on the word "prodigious," and comes from the fact that the host sometimes in the chalice in the Catholic church has a red growth upon it, which is declared to be the blood of Christ. This red growth was investigated, and it was found to be a micro-organism, producing a red material within its cell. It grows freely on all media, but does not grow in the river water. It has been rarely found in the river waters of this country, and it is not common to the domestic waters of the United States, although it is said to be found in abundance in some of the waters of Egypt. It liquifies gelatine and is non-motile.

In the examination made in the waters of the respective rivers in August, 1899, and extended through until August, 1900, every sample was closely inspected for the purpose of disclosing the distinctive form of micro-organism found. In none of the samples could the bacilli of prodigiosus be found. The conclusion was therefore reached that it was not a normal inhabitant of the streams under investigation. Ten thousand samples of water have been examined without it having been found. On the 31st day of August, 1900, a forty-gallon whiskey barrel, containing forty gallons of broth culture of bacilli prodigiosus, containing over one thousand million bacteria per cubic centimeter, was emptied into the Mississippi river just below the mouth of the Illinois river.

On the 3rd day of September, three days later, this organism was found in a sample of water collected in the river at Alton.

On September 20th the experiment was repeated: A barrel containing forty gallons of bacillus prodigiosus broth was emptied at the same point, and on the 23rd of September the organism was found in a sample of water collected on the Illinois shore at the Chain of Rocks.

On October 18th this bacterium was found in a sample of water from the laboratory tap in the old City Hall, St. Louis.

On October 24th it was found in a sample collected on the Illinois shore, Chain of Rocks.

On the evening of November 6, 1901, 107 barrels of prodigiosus broth, containing forty gallons each, with over one thousand million prodigiosus bacteria per cubic centimeter
132 were deposited in the Chicago Drainage Canal a few miles east of the Bear Trap Dam at Lockport.

On December 4, 1901, bacilli prodigiosus was found in a sample of water collected from Intake Tower, Chain of Rocks, and in another sample collected from the same place on December 5th.

On December 6, 1901, it was found in a sample collected at Grafton, Illinois.

On December 7, 1901, it was found in a sample collected from the Illinois river at Grafton.

Dr. Ravold made experiments as to the longevity of the bacilli prodigiosus in samples of water collected in the Chicago river, Drainage Canal, Illinois river at Peoria and the Laboratory tap at St. Louis. It was found to live in the non-sterilized water of Drainage Canal at Joliet seven days and Chicago river eleven days. In the Drainage Canal at Lockport thirty-two days. In the Illinois river at Pekin fifty-three days.

In the refrigerator in the dark it was found to live for a period of thirty-one to fifty-three days, and in the above non-sterilized water, exposed to sun light, it survived eleven days, while the bacilli typhosus in the same water, under similar circumstances, lived from ten to twenty-one days.

(Dr. Ravold's testimony, printed record, Volume 1, pp. 779-788, inc.)

During the period of the above investigation the waters were cold and there was no opportunity for multiplication of the bacilli.

(Dr. Ravold's testimony, printed record, Volume 1, p. 920.)

A careful examination was made, so that no mistake could be made, as to whether or not the bacilli discovered were those of prodigiosus, as shown by the following excerpt from the cross-examination of Dr. Ravold.

"We allowed the plates to rest as long as possible, to gather the red color, and the plate might liquify before the color appears. It is impossible to say anything about the number 133 on a plate.

"*Q. When you discovered the red color you had accomplished all you were looking for and ceased.*

"*A. No, the red color was an indication that a bacillus producing a red pigment was there; that bacillus had to be separated out in a pure culture and put through all its cultural characteristics and studied for form. In fact we searched thoroughly to see whether it was the one we put in the canal or not, and compared it with the ones put in.*

"Q. Were you able to identify it as the genuine article?

"A. It had no label on it; no name blown on the bottle, or anything of that kind, but it behaved like the original culture.

"Q. It was of good behavior, was it?

"A. Yes, sir.

"Q. Doctor, have you ever examined any of the waters on this continent for the purpose of ascertaining the presence of the bacillus prodigiosus other than that which you have just mentioned?

A. "No, sir; I have never undertaken such a tremendously extensive investigation as was included in this work on the Drainage Canal and the Illinois river, but I have never found it in any of the waters which I have examined in this country, and my laboratory assistant, my associate, was Mr. Johnson, as clever a water bacteriologist as there is in this country. He worked continuously on the Ohio river above Louisville and Cincinnati, for two or three years, and did not find it in that water, and I understand that a bacteriologist who worked at New Orleans—one of them told me this—that he once found the prodigious in the Mississippi river near New Orleans, after we had emptied it into the Drainage Canal.

"Q. And then as far as your knowledge extends, and from personal knowledge and from information of others, all examinations on this continent heretofore have not revealed the presence—

"A. Not in large numbers.

"Q. —of this bacteria?

"A. I would say it has been found a very few times—I
134 searched the literature on the subject—in the waters of the United States.

"Q. What were the peculiar characteristics of this bacterium that enabled you to identify it?

"A. It is one of the most easily identified of all bacteria.

"Q. In what respect?

"A. In its pigment production.

"Q. Color?

"A. The pigment that it produces. It liquifies gelatine and produces pigment; it coagulates milk and turns that milk red without digesting the casein which is the result of the coagulation, and makes it very characteristic at once.

"Q. But all bacteriological examinations carried on with the view to ascertaining the quantitative presence of bacteria in running water or lake waters reveal the presence of this bacterium?

"A. Yes, sir.

"Q. They would?

"A. Oh, yes; every man who studies water quantitatively. Every bacteriologist is mad in the search of new forms. He wants to have a bacillus named after him if he can, or he wants to find one and name it. He wants to have his name go down in literature as associated with a bacterium—every man that plates a specimen of water is searching that water constantly for new forms.

"Q. Well, doctor, there are a great many examinations of this kind that have been carried on in recent years?

"A. Yes, sir.

"Q. All over this country?

"A. All over this country.

"Q. And you will not say that no other bacteriologist than those you have mentioned, and yourself, have not found this—

"A. Oh, no.

"Q. —particular bacterium in the waters of the United States?

"A. No, I couldn't say that.

"Q. You simply haven't found it, and those with whom
135 you have conversed, whose names you have mentioned, have not found it?

"A. I see also from your investigation, the book published by the State Board of Health of Illinois, I don't see the prodigiosus named among the bacteria found by the Northwestern men.

"Q. In the waters of the Illinois river?

"A. Yes, although they have not quite a number of bacteria separated out, as distinctive for these waters.

"Q. That report, however, did not include any specimens taken from the waters of Lake Michigan, did it, with the view to this particular bacteria?

"A. I don't know whether it did or not.

"Q. Have you ever made any examinations of the waters of Lake Michigan?

"A. Yes, sir; oh, yes.

"Q. Did you make that examination in connection with this investigation?

"A. Yes, I have had samples collected, and the water was studied thoroughly, and I gave you the—

"Q. All the flora?

"A. I gave you all the bacteriological flora found by us in the Lake Michigan water. That has already been submitted in evidence.

"Q. And you didn't find in those examinations any evidence of the presence of the bacillus prodigiosus?

"A. No, sir; nor in the Chicago river or the Drainage Canal.

"Q. You have stated all that in your previous examination?

"A. Oh, yes; that has already been gone over.

"Q. That is all in the record?

"A. Yes, sir.

"Q. Now, what is your opinion as to the probability

reproduction or multiplication of numbers of the bacillus prodigiosus after being deposited in the waters of the Drainage Canal?

"A. As I said before, that point was kept clearly in mind
136 before the bacteria were deposited—the water was cold, almost to the freezing point, before the bacteria were put into the water. We felt perfectly confident that there would be no multiplication of micro-organisms under these conditions of temperature and nutritive pabulum, etc., which would surround the bacteria in the waters of the Drainage Canal or the Illionis river.

"Q. So, then, it is your opinion—

"A. So, it is my opinion that these micro-organisms did not multiply in the transit from the point where they were put into the canal to the Intake, and if they did so, it was very feebly so because they do not multiply under the conditions named; they do not multiply below 10 degrees centigrade.

"Q. What would be the temperature of your water mains in reference to their possibility of reproduction?

"A. Here?

"Q. Yes, in the city of St. Louis?

"A. Well, the temperature of the water running from the tap at that particular time; I don't remember, but we took the temperature of the water from the tap during this period, and that is on record. I haven't the record with me, but the temperature would be higher than in the water of the running stream.

"Q. It would not be quite so cold?

"A. No.

"Q. But would it be up to a point at which there would be a probability of reproduction or multiplication of species?

"A. Not the production, no. It was low, but above freezing."

(Dr. Ravold's cross-examination, printed record, Vol. 1, pp. 923-924-925-926-927.)

Mr. Whipple, at page 2002, stated his unqualified opinion to be that the bacilli prodigiosis discovered in samples of water collected at the mouth of the Illinois river, and at the St. Louis waterworks by Dr. Ravold and his assistants, constituted a portion of the bacilli which were contained in the hundred and six barrels of bacilli prodigiosis deposited in the Chicago
137 Drainage Canal at Lamont. (Vol. 2, page 2002.)

This opinion was concurred in by Prof. Sedgwick in the following words:

"This interesting and valuable experiment, as I regard it, seems to me to show that typhoid germs might pass from the drainage canal through the Des Plaines and Illinois rivers, and be carried alive to the intake at the Chain of Rocks, and then to the supply of water, thereby producing typhoid fever at the city of St. Louis. (Vol. 3, page 2204.)"

13.

THE MISSOURI RIVER IS SUBJECTED TO THE DRAINAGE FROM SALT BEDS IN KANSAS, THUS PRODUCING LARGE QUANTITIES OF CHLORINE IN THE RIVER.

In the chemical analysis of the waters of the respective rivers it was found that the Missouri river contains more chlorine than the upper Mississippi, and some less than the waters of the Illinois, and much less than the waters of the Illinois river at La Salle, Peoria and elsewhere. The chlorine in the Mississippi river is explainable from the fact that it runs on an average with the chlorines of other rivers having similar pollutions sewering into it. The large quantities of chlorine in the Illinois river are explainable only from the immense population of Chicago, and the Sanitary District of Chicago, there being no salt beds upon the watershed of either the Illinois or the Mississippi rivers. It is a well known historical fact that upon the Missouri river are situated large beds of salt, ranging in depth from ten to more than three hundred feet.

In a tabular presentation of salt deposits of the United States, published by the United States under the title, "Useful Minerals of the United States," we find the following on page 732:

"Common salts, brines and rock salts, extensive deposits in
138 the central part of Kansas, at Ossawatomie, several wells near Hammond, in Brown county, brines in the valley of Fall river, brine in wells at Mound City, Lynn county, State Salt Springs and other salt marshes in the belt crossing Solomon, Republican and Saline counties, eighty by thirty-five miles, rock

salt in beds six to twenty-eight inches deep, with salt industries at Solomon City, Saline county; Junction City, Davis county; rock salt at Anthony, seventy-five feet thick, in Harper county; many borings at Ellsworth, one hundred and forty feet thick, and at Lyons two hundred and fifty feet thick."

The above Republican river, Solomon river and Saline valleys are tributary to the Kaw river, which is three hundred miles long and drains through several of the counties containing large deposits of salt and empties into the Missouri river at Kansas City.

(See Teichmann's testimony, Vol. 2, page 1690; Keiser's testimony, Vol. 2, pp. 1722-3-4-5, and Whipple's testimony, Vol. 3, page 2091.)

14

MIXING OF THE ILLINOIS, MISSOURI AND MISSISSIPPI RIVER WATERS AT AND ABOVE THE CHAIN OF ROCKS.

That the water of the Illinois river mixes with the water of the Mississippi river below Grafton is clearly demonstrated by examination of the chlorine contained in the waters of the respective rivers. It will be found that the chlorine on the Missouri shore is higher than the chlorine at the Intake tower, demonstrating that the water at the intake tower is not altogether Missouri river water because the Missouri river contains a larger quantity of chlorine than the Mississippi. It is also shown that the chlorines at the Intake are higher than the chlorines in the water in the Mississippi above Grafton. It therefore becomes conclusive that the large quantity of chlorine entering at the Intake must come from the Illinois river, the Illinois river above Grafton containing a larger quantity than the Missouri
139 or Mississippi. (See Teichmann's evidence, Volume 2, 1221-2-3.)

The mixing of the water of the Mississippi and Missouri rivers was determined by Prof. Teichmann, based upon the total of solids contained in samples of water collected from the Mississippi and Missouri rivers. The table of percentages from January 24, 1900, to October 10, 1900, is as follows:

Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
January	24	220	73	27
	25	90	56	4
	26	305	78	22

Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
January	27	280	87	13
	28	230	100	0
	29	170	53	47
	30	250	69	31
	31	210	78	22
February	1			
	2	120	58	42
	3	70	58	42
	4	80	62	38
	5	140	93	7
	6			
	7	0	0	100
	8			
	9	60	22	78
	10	200	38	62
	11			
	12	80	53	47
	13	370	65	35
	14	510	77	33
	15	700	88	12
	16	1785	98	2
March	4	190	79	21
	8	1810	79	21
	9	720	57	43
	10	980	67	33
	11			
	12	1225	53	47
	13	1680	67	33
	14	1895	81	19
	15	1870	68	32

Date 1900		Intake Minus Hartford	Percentage Mo. R...	Percentage ...iss. River
March	17	1410	62	38
	18	1140	52	48
	20	350	31	69
	21	470	80	20
	22	114	9	91
	23	85	11	89
	24	...	0	100
	25	...	0	100
	26	...	0	100
	27	...	0	100
	28	...	0	100
	29	188	38	62
	31	...	0	100
April	1	80	12	88
	2	410	50	50
	3	400	44	56
	4	380	37	63
	5	480	44	56
	6	720	68	32
	7	...	100	0
	8	675	55	45
	9	690	52	48
	10	820	65	35
	11	650	55	45
	12	630	45	55
	13	790	52	48
	14	1695	67	33
	15	...	100	0
	16	...	100	0

	Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
141	April	17	1441	45	55
		18	1383	70	30
		19	1078	54	46
		20	884	45	55
		21	1153	63	37
		22	822	21	79
		23	1154	78	22
		24	739	65	35
		25	44	9	91
		26	906	82	18
		28	934	63	37
		29	870	68	32
		30	782	80	20
	May	1	790	66	34
		2	840	67	33
		3	990	71	29
		4	1155	61	39
		5	1070	49	51
		6	430	26	74
		7	955	60	40
		8	358	42	56
		9	845	62	38
		10	745	51	49
		11	717	59	41
		12	810	56	44
		13	1431	82	18
		14	1737	55	45
		15	1700	66	34
		16	1545	79	21

Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
May	17	1480	72	28
	18	1645	68	32
	19	1851	90	10
	20	1440	87	13
	21	1495	81	19
	22	1487	86	14
142	23	1467	82	18
	24	1481	83	17
	25	1402	83	17
	26	1377	75	25
	27	1303	81	19
	28	1478	100	0
	29	1702	94	6
	30	1865	89	11
	31	...	100	0
June	1	1680	94	6
	2	1615	74	26
	3	1845	95	5
	4	...	100	0
	5	1695	85	15
	6	1660	86	14
	7	1540	79	21
	8	1433	72	28
	9	1630	81	19
	10	1605	75	25
	11	1515	95	6
	12	...	100	0
	13	1620	94	6
	14	3635	91	9
	15	...	100	0

Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
June	16	...	100	0
	17	...	100	0
	18	2072	94	6
	19	...	100	0
	20	1670	91	9
	21	1795	94	6
	22	2740	93	7
	23	...	100	0
	24	...	100	0
	25	...	100	0
	26	...	100	0
	27	2685	99	1
	28	2415	84	16
	29	...	100	0
	30	...	100	0
July	1	...	100	0
	2	...	100	0
	3	...	100	0
	4	...	100	0
	5	2660	74	26
	6	...	100	0
	7	...	100	0
	8	...	100	0
	9	...	100	0
	10	3070	88	12
	11	...	100	0
	12	...	100	0
	13	...	100	0
	14	...	100	0
	15	...	100	0

	Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
	July	16	2135	94	6
		17	1990	92	8
		18	1570	77	23
		19	1973	95	5
		20	1440	86	14
		21	1430	87	13
		22	...	100	0
		23	2416	99	1
		24	2900	81	19
		25	3090	73	27
		26	2869	85	15
		27	2020	76	24
		28	1921	84	16
		29	...		
		30	1587	83	17
		31	1460	94	6
144	August	1	1273	79	21
		2	1312	100	0
		3	1238	82	18
		4	1248	87	13
		5	999	78	22
		6	1078	89	11
		7	743	61	39
		8	764	77	23
		9	703	75	25
		10	701	75	25
		11	730	75	25
		12	655	81	19
		13	598	78	22
		14	604	75	25

Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
August	15	590	81	19
	16	576	75	25
	17	575	67	33
	18	630	90	10
	19	778	73	27
	20	988	85	15
	21	900	65	35
	22	860	73	27
	23	760	71	29
	24	782	85	15
	25	736	76	24
	26	736	76	24
	27	820	94	6
	28	977	85	15
	29	951	83	17
	30	750	50	50
	31	750	50	50
September	1	885	94	6
	2	1030	99	1
	3	969	82	18
	4			
	5	1124	72	28
	6	1175	96	4
	8	1082	84	16
	9	1056	87	13
	10	900	83	17
	11			
	12	674	60	40
	13	708	73	27
	14	583	67	33

	Date 1900		Intake Minus Hartford	Percentage Mo. River	Percentage Miss. River
145	September	15	598	74	26
		16	555	60	40
		17	570	67	33
		18	553	60	40
		19	524	60	40
		20	659	56	44
		21	1069	57	43
		22	1597	54	46
		23	1593	60	40
		24	1650	59	41
		25	1476	67	33
		26	1320	65	35
		27	920	66	34
		28	975	64	36
		29	925	68	32
		30	973	68	32
	October	1	913	65	35
		2	965	59	41
		3	1542	61	39
		4	877	36	64
		5	1642	72	28
		6	1519	72	28
		7	1567	58	42
		8	1521	68	32
146		9	1740	77	23
		10	1791	74	26

(Teichmann's testimony, Vol. 2, page 1240.)

Prof. Keiser, at page 1050 of his testimony, also made determinations as to the percentage of Mississippi river water en-

tering the intake of the St. Louis water supply as compared with the amount of Missouri river water entering it.

See also Whipple's testimony, Vo. 2, pp. 1892-3-1991-2151.

By reason of the velocity of the Illinois river, the momentum of the particles delivered into the Mississippi would be such as to carry them out into the stream; in fact, it is observed that when the Illinois river is in flood the waters pass well out into the main stream of the Mississippi river. The distribution of velocites and distribution of pressures has much to do with the mixing. The swifter flowing water transmits less pressure to the water adjacent to it, and consequently the Illinois river entering the Mississippi at a lower velocity than the Mississippi is flowing, the waters of the Illinois would be drawn, or forced, to mingle with the Mississippi river, just as we are enabled to pump water by means of the jet pump where we deliver a jet of water through a channel at a high velocity, and that entrains with it slower moving water at its side and carries it out of the place where it originally was. In other words, to express it in more popular language, the swifter moving stream exerts a suction upon the water of the slower moving stream which leads to the dissemination and mixing of the latter through the former. (Williams, Vol. 3, pp. 2434, 2435.)

15.

MOST CONCLUSIVE EVIDENCE OF THE SANITARY QUALITY OF THE WATER SUPPLY.

The best criterion of the sanitary quality of the water supply that is being used by a community for domestic purposes is the presence or absence of water-borne diseases among the
147 sources of the supply, and especial reference and consideration may be given to typhoid fever, as it is at present the most important of the water-borne diseases.

(Williams' testimony, Vol. 3, pp. 2462-3-4-5-6-7.)

The fact that the chemical analysis of water fails to show the presence of disease producing infection is no evidence to an expert that no such infection may exist in the water.

(Williams' testimony, Vol. 3, pp. 2462-3.)

The reason given for the failure of chemical analysis to disclose disease producing organisms which are recognized as being contained in polluted water is that the infectious quality of the water is not dependent upon its chemical constituents, but upon the presence of the living organisms themselves, which are of such minute character that they pass entirely beyond the range of chemical analysis to detect, and yet are contained in the water in sufficient quantities to cause very serious results in the event the water be used for drinking and domestic purposes. What is true with reference to the chemical analysis may also be applied to the science of bacteriology. Such minute quantities of the water are examined as compared with the entire volume used that bacteriology fails in its application to disclose disease producing bacteria, although they may be scattered

about in the water in variable quantities. This fact was excellently broaght out by a series of analyses made of the River Dee, in Scotland, whereby a series of analyses simultaneously made showed the bacteria contained in the water to be thousands in a cubic centimetre of water, while the chemical analysis was entirely unable to detect the presence of the added microbes; so in the waters of the Detroit river, chemists, in their analysis of the water, expressed themselves as entirely unable to detect any evidence of pollution, while the records of the city showed at the same time a tremendous epidemic of typhoid fever due to the water, which was being analyzed. It is, however, essential that whenever chemical, microscopical and bacteriological analyses of the water indicate the presence of substances which are known to be related to infectious matter, to
148 give the evidence of these analyses great weight in estimating the quality of the water, and an expert should not recommend such water for use until he becomes satisfied that the source of the organisms so found by him in the water which constituted the impurities are such as to be unlikely to affect the sanitary quality of the water. On the other hand, it is not necessary for the expert to depend or require either a chemical or microscopical or bacteriological analysis of water to determine its pollution.

It may also be said that while the bacilli coli communis is an important index to sewage pollution, the fact that they are not constantly found in every sample examined is not positive assurance that the water has become more suitable in character and less liable to infection.

(Williams' testimony, Vol. 3, pp. 2464-5-6-7.)

16.

THE EFFECT OF THE OPENING OF THE CANAL IN CHICAGO UPON THE ST. LOUIS WATER SUPPLY.

The population of the city of Chicago, according to the census of 1900, was 1,650,000.

The population of the State of Illinois in the vicinity of Chicago, which also discharges its sewerage in the Chicago Drainage Canal above Lockport, at which point the controlling works of the Chicago Drainage Canal is situated, is roughly estimated at 350,000. It is a conservative statement to say at this time the sewerage from a population of 2,000,000 is discharged into the canal and thence into the Des Plaines and Illinois river.

(Dr. Ravold's testimony, printed record, volume 1, page 767.)

The waste of 2,000,000 people is emptied into the Drainage Canal above Lockport, twenty-seven miles from the city of Chicago proper. There is about three ounces of excrementious matter and forty ounces of urine per day of twenty-four hours in the sewerage of a city, for each person residing in it.
149 This would represent about 190 tons per day of solid excrementitious matter and about 670,000 gallons of urine discharged into the canal at Chicago each day of twenty-four hours. The water consumption per day at Chicago is something like 360,000,000 gallons per day for the entire population. This, together with the natural discharges, represents the combined sewerage discharge of the Sanitary District of Chicago per day. The maximum discharge of water through the Canal into the Des Plaines river is 300,000 cubic feet per minute, which, when mixed with the sewerage of Chicago, represents a dilution of

one to nine, or one part sewerage to nine parts Lake Michigan water. With this dilution it is readily seen by a perusal of the bacteriological results obtained from samples collected at Lockport that the diluted sewerage does not approach in the slightest degree a resemblance to a sanitary water.

(Dr. Ravold's testimony, printed record, volume 1, pages 769-770.)

At times dead fish were seen floating over the Bear Trap Dam from the Canal. In November, 1900, as many as 500 were observed to pass over in a period of ten minutes.

(Dr. Ravold's testimony, printed record, volume 1, page 770.)

The Des Plaines river at Joliet, exclusive of the water added to it by the Chicago Drainage Canal, is a very small stream, as is also the Illinois river at its source.

The population, urban and rural, of the Illinois river basin, exclusive of Chicago and the Sanitary District of Chicago, is stated by Dr. Ravold at 1,305,503, while the population of the Sanitary District of Chicago is about 2,000,000 or 45,000 more than the entire population residing in the natural basin of the Illinois river.

(Dr. Ravold's testimony, printed record, volume 1, pages 775-776.)

The average number of deaths from typhoid fever per annum at Chicago for some years past has been about 360, which represents more than 8,500 cases per year. By the opening of the canal the waters of the Illinois river have become subjected to and infected with the typhoid bacilli of this large number of patients. More striking does this appear and more certain is its effect on the waters of the Illinois and Mississippi river when we take into consideration the fact that typhoid

bacteria to the number of 172,000,000 per cubic centimeter are found in the urine of a person sick of the disease.

(Dr. Ravold's testimony, printed record, volume 1, page 789.)

From the foregoing statement it is not surprising that the following bacterial results were obtained by Dr. Ravold in his examination of the waters of the Illinois river after the Drainage Canal had been opened. After setting forth tables showing the number of bacteria per cubic centimeter found in the respective waters for the respective times, Dr. Ravold stated that the bacilli were highest in the Canal at Lockport from the 17th to the 23rd of November, 1900, and that they were still high on the 25th of November at points below Lockport.

At Peoria there was a rapid rise immediately following the 17th of November, Peoria being 125 miles below Chicago. This rise at Peoria corresponds with the rise and fall of bacilli at Bear Trap Dam, Rubey street and Brandon's Bridge at Joliet during this same period.

During this period the stage of the river remained remarkably even throughout, and the bacteria was some higher, and the water was a little bit lower than it had been the previous weeks.

(Printed record, volume 1, pages 450-459.)

It indicates therefore that a large number of bacteria put in the Chicago river came through to Peoria.

(Printed record, volume 1, page 459.)

At Grafton, 163 miles below Peoria, during the month of November, 1901, there was an apparent increase in bacteria. Corresponding with the increase during the same period or

151 immediately before, at Peoria and Lockport, the number of bacteria at the high points during the month at Grafton is 34,000. The river was lower at that time than it had previously been.

(Printed record, volume 1, pages 460-462.)

A comparison of the bacterial counts of the waters contained in the Illinois river prior to the opening of the canal with those obtained since the opening sufficiently demonstrates that the water of that river is more highly polluted since the opening of the canal than prior thereto, and this, too, regardless of the fact that from 250,000 to 300,000 cubic feet of water per minute from Lake Michigan is being continuously added to the force and volume of water flowing down into the Illinois river.

Dr. Ravold, in his testimony, with reference to the condition of the water in the Illinois river and its effect upon the Mississippi river water immediately after the opening of the Drainage Canal, stated as follows:

Our work upon the rivers indicated, and we are pretty confident about that, that the first discharge of the Chicago river through the Drainage Canal at the opening, which occurred on the 16th or 17th of January, 1900, reached here by the 29th or 30th of January, and passed, at which time, fortunately for St. Louis, the Missouri river was very high. At that time I thought over the question as the source of this pollution and looked over the samples microscopically, and my conclusion was this, if you care to hear it. This mass of filth that was in the Chicago river and in the Drainage Canal while it was retained there, after the waters of the Drainage Canal were allowed to stand or the waters of the Chicago river were allowed to stand in the Drainage Canal for a time without being discharged. The opening of the canal discharged the water over the dam and it came rush-

ing down the Illinois valley and traces of it could be seen with the unaided eye for a great distance, as the water traveled along. The Illinois river was not high at that time. The great part of the solid suspended matter was carried down, making a black nasty mud in the stream. It was also winter time
152 and the anaerobic bacteria were not at work, consequently they had not destroyed the organic sediment.

(Dr. Ravold's testimony, printed record, volume 1, pages 839-840.)

(Keiser's testimony, pages 988-989.)

On cross-examination Mr. Springer asked the following question:

Then, so far as your analysis is concerned, you charged up all the impurities that you found at Grafton to the Drainage Canal?

To which Professor Keiser answered as follows:

Well, in this way, as we ascended the river and we found the impurities steadily increasing, as we went up the river, I reasoned that if the impurities came slightly from the tributaries of the river, the quantity of free ammonia and albuminoid ammonia and nitrites would be pretty constant on the way up the river and up through the tributaries if the waters were homogeneous, they would show that on analysis, but we found a very great increase all the way to Joliet, at which point the analysis shows the water to be diluted sewage.

The increase in impurities consisted of free ammonia, nitrites, chlorine and albuminoid ammonia.

(Prof. Keiser's testimony, printed record, Volume 2, pages 1109-1110.)

The average amount of chlorine found in the Mississippi river above Grafton is from four to five parts per million. Im-

mediately below Grafton, after it has received the waters of the Illinois river, the quantity of chlorine is increased from 4 to 16 parts per million. So that from the chemical standpoint it will be readily observed that the Illinois river contributed largely to the increase of chlorine in the water of the Mississippi river.

(Prof. Keiser's testimony, printed record, Volume 2, page 1110.)

(Cross-examination of Prof. Keiser, Volume 2, pages 1127-1148.)

153 According to the chemical observations made by Professor Teichmann of the water of the Mississippi river and the Illinois river above Grafton, as shown by table No. 1 of Professor Teichmann's testimony, the following general average results were obtained for the year 1899, estimated in parts per million, total residue on evaporation:

Illinois river above Grafton, average..... 413
Mississippi river above Grafton average..... 340

Samples from which the foregoing average results were obtained were collected between September 6, 1899, and January 6, 1900, near the mouth of the Illinois river.

NITROGEN AS AMMONIA.

Illinois river above Grafton, general average..... .215
Mississippi river above Grafton..... .069

ALBUMINOID AMMONIA.

Illinois river above Grafton..... .317
Mississippi river above Grafton..... .314

NITROGEN AS NITRITES.

Illinois river above Grafton..... .012
Mississippi river above Grafton..... .002

NITRATES.

Illinois river above Grafton..... .8
Mississippi river above Grafton..... .3

Samples from which the foregoing average results were obtained were collected between September 6, 1899, and January 6, 1900, near the mouth of the Illinois river.

(Prof. Teichmann's testimony, printed record, Volume 2, page 1177.)

From October 16, 1899, to January 22, 1900, free ammonia samples were collected at the Intake, Chain of Rocks. The
154 average results of the examination, expressed in parts per million, were as follows:

Nitrogen as free ammonia..... .0063
Nitrogen as Nitrites..... .002
Nitrogen as Nitrates..... .4
Nitrogen as Chlorine..... .17

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1180-1181.)

A comparison of these results with results obtained since the opening of the Drainage Canal show that the Mississippi river has retained its condition of stability since the opening of the canal, while the Illinois river above Grafton and the Mississippi river below Grafton have experienced a great increase in polluting and contaminating constituents.

The testimony of Dr. Teichmann is based upon his personal analysis and observation of a large number of samples of water collected from the following named points:

Lake Michigan.

Drainage Canal above Bear Trap Dam at Lockport.

Des Plaines river at Joliet.

Illinois river three miles above Peoria.
Illinois river at Wesley immediately below Peoria.
Illinois river at Pekin bridge.
Illinois river three miles below Pekin.
Illinois river three miles above Grafton.
Mississippi river two miles above Grafton.
Mississippi river one mile above Alton.
Mississippi river opposite Hartford.
Missouri river opposite Fort Bellefontaine.
Mississippi river near Missouri shore, Chain of Rocks.
Mississippi river near Illinois shore, Chain of Rocks.
Mississippi river at Chain of Rocks.
Intake Tower.
The Wet Well of St. Louis Waterworks.
Outlet reservoir, St. Louis Waterworks.
Tap at City Chemist's office, St. Louis.

155 During the period of the investigation, samples were collected daily, which were analyzed and from which weekly, monthly and periodically averages were determined and expressed.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1182-1183.)

An examination of the chart and exhibits read in evidence by Dr. Teichmann show the result of the chemical analysis of water of the respective rivers after the opening of the Drainage Canal.

Immediately after the opening of the canal the Illinois river below Joliet became very much increased in polluting material. The results clearly show an enormous pollution caused by flushing out the Chicago river and the canal. The amounts of free ammonia, chlorine and nitrites represents the effect produced. It will be observed that in January, immediately after the open-

ing of the canal, chlorine ran up from 21 to 28 parts per million at Peoria. This is followed by an increase at Grafton from 15 to 23 parts per million. Chlorine running very much together in their fluctuations at Peoria and at Grafton.

In regard to free ammonia, it will be noticed that the condition three miles above Grafton is caused by large quantities of free ammonia three miles above Peoria. Thus following the opening of the Drainage Canal, we find a great raise in the free ammonia at Peoria, and afterwards a corresponding raise at Grafton, and as this decreased at Peoria it is found to decrease at Grafton.

The action of nitrites in the water corresponds with that of free ammonia, thus high nitrites in the Illinois river above Peoria is afterwards followed by high nitrites above Grafton.

As to the stability of the respective waters, it will be observed from these analyses that nitrites raise and fall in the Illinois river above Grafton, and show much higher in results than the Mississippi river above Grafton.

Chlorines are much lower in the Mississippi river during
the entire year. In fact, all of the chemical constituents
156 abruptly change in the Illinois river, while they remain at
a permanent stage in the Mississippi river.

The Illinois river at Grafton is shown to be in a fermentative state, the process of purification not having been completed as shown by high nitrites, free ammonia and nitrates. While the stability of the waters in the Mississippi river is shown by low nitrites, free ammonia and chlorine, which run practically the same throughout the entire period.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1198-1212.)

From the chemical analyses made with the water of the Illinois river by Professor Teichmann, it will be observed that

the water of that river, after the opening of the Canal, was unable to completely recover itself within the time required for the water to flow from Chicago to St. Louis.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1215-1216.)

For the week beginning January 30th, the average result of free ammonia in the Illinois river at Grafton amounted to 1.675 parts per million, while in the Mississippi river, a few miles above the mouth of the Illinois, the corresponding average was .175, which is only one-tenth of the free ammonia that was found in the Illinois river above its mouth.

At Alton and Hartford free ammonia was found, average 1.055 and .865 parts per million, respectively.

So it will be observed that there was a remarkable increase in free ammonia in the Mississippi river after it had received the waters of the Illinois river.

What is true with reference to free ammonia holds good as to nitrites, nitrates and chlorine.

An observation of the examination of the Missouri river water shows less contamination than in the Mississippi river, so that the unquestionable conclusion must be accepted that
157 a large percentage of the polluted material found in the water supply of the city of St. Louis comes from the Illinois river.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1222-1223-1224-1225 and 1245.)

The water of the Mississippi entering into the intake during the period from 1895 to 1899, inclusive, was more safe from a sanitary standpoint after it had been settled in settling basins and delivered to the consumers than it is today. From an examination of the typhoid statistics of St. Louis during the period

from 1895 to the end of the year 1902, which show that in 1895 there were 106 deaths; in 1896, 107 deaths; in 1897, 125 deaths; in 1898, 95 deaths; in 1899, 130 deaths; in 1900, 168 deaths; in 1901, 197 deaths, and in 1902, 222 deaths, it will be found that the average number of deaths in the five years from 1895 to 1899, inclusive, was 112 per annum, while the average annual deaths for the three years beginning with January, 1900, was 196, showing an increase in round numbers of about 80 per cent.

Taking into consideration the differences in population, that is, the increase in population during that period, and expressing the typhoid fever deaths with reference to the number per hundred thousand of population living, there has been an increase during the past three years on an average of about 77 per cent over the annual typhoid death rate per one hundred thousand population living for the five years, 1895 to 1899, inclusive.

Comparing the number of deaths from typhoid fever during these eight years, with reference to the total number of deaths from all causes occurring in the city of St. Louis, and obtaining the percentage of mortality from typhoid fever, the percentage of increase for the last three years on an average as compared with the average percentage of mortality from typhoid fever during the preceding five years is 73 per cent. The average number of deaths from typhoid fever in St. Louis during the past five years under consideration was about 20.4 per hundred thousand population, and at this rate during the past three years, on an average, was about 32.3 on the same basis per hundred thousand population, so that it will be observed from this standpoint that the St. Louis water supply can
158 not be classed as a good water, and must be considered as having become more infected with disease producing or-

ganisms than prior to the opening of the canal, the manner of treatment during the entire period being essentially the same.

(See Fuller's testimony, Vol. 3, pp. 2610 and 2615.)

After familiarizing himself with typhoid fever statistics in the larger centers of population of the Mississippi river watershed above the Chain of Rocks, excluding the Sanitary District of Chicago, during the period from 1895 to 1902, inclusive, Mr. Fuller made the following remarks:

"During these periods there have been at quite a number of points some variations in the amount of typhoid fever prevailing in different years. Taking the typhoid fever statistics upon this watershed area as stated, as a whole, but excluding the Sanitary District of Chicago, based upon the average number of deaths from typhoid fever per year, it is my judgment, viewing the matter as a general proposition, that there has not occurred on the natural area of the Mississippi watershed above St. Louis any increase in the number of deaths sufficient to explain to any material degree the less safe condition of the Mississippi river water as taken from the intake tower of the St. Louis waterworks, during the last period, as compared with the period 1895 to 1899.

"In my judgment, the Chicago Drainage Canal renders the water of St. Louis less safe than it was prior to January, 1900."

(See Fuller's testimony, Vol. 3, pp. 2613 to 2620, inclusive; Hazen's testimony, Vol. 3, p. 2838.)

The effect of the water of the Mississippi river upon the people of St. Louis immediately after the opening of the Chicago Drainage Canal will be readily appreciated when the typhoid mortality of the city is examined and compared with previous periods. The canal was opened January 17, 1900, and allowing time for the passage of the water from Chicago to St.

Louis, time for the incubation of the germ in the patient and the average time for sickness and death, it is observable that an increase of 1,300 per cent in deaths took place in March,
159 1900, over conditions existing during the same month in the years 1895-6-7-8-9, respectively.

(See Teichmann's testimony, Vol. 2, pp. 1241-2.)

The typhoid conditions in St. Louis, after the opening of the drainage canal is a very striking demonstration of the increase of the pollution of our water supply had from the polluting effect of the waters of the Drainage Canal and the waters of the Des Plaines and Illinois rivers upon the Mississippi river. It is apparent that there is a striking correspondence in the increase in pollution in the river during the month of March, 1900, with an increase of typhoid in February of 1,300 per cent over the average for that month for the five preceding years, the typhoid results for the month of March, 1900, becoming almost epidemic, and immediately following the pollution of the water supply traced to Grafton, thence to the Des Plaines, and thence to the Chicago Drainage Canal. The effect of the opening of the canal was followed by a pollution higher than was ever before experienced in the history of the city of St. Louis, and this pollution, highly contaminated as it was with typhoid bacilli, did not escape the intake tower and the St. Louis water supply, as evidenced by the large number of deaths and cases from typhoid fever in the city immediately following.

(Teichmann's testimony, Vol. 2, pp. 1445-6.)

Prof. Sedgwick stated that he had made a very careful study of the typhoid fever statistics of the city of St. Louis, and of the physical surroundings conducive thereto. During the period of fifteen years prior to January 1, 1900, the typhoid death rate in St. Louis was not above that of some cities provided with

water supplies considered poor. During the period following the removal of the intake from Bissell's Point to the Chain of Rocks the typhoid death rate of St. Louis was remarkably good, lower than it had been for some time, and lower than the death rate for the city of Boston for the same period. Beginning with the first day of January, 1900, there has been a remarkable annual increase in the typhoid death rate of the city of St. Louis, so
that during the last period it has not only been higher than
160 during the previous five years, but has been higher than at
any time in its own history since 1885, excepting during the epidemic of 1892, and very much higher than the death rate in the city of Boston, with which it previously compared very favorably. The increase in typhoid fever deaths in St. Louis since January 1, 1900, as compared with the preceding fifteen years, has been 26 per cent, while the increase since January 1, 1900, in the annual mortality as compared with the preceding five years has been 73 per cent. The water supply of Boston is considered fairly good, and the typhoid rate of that city has been and is below that of most cities of a similar size. Boston and St. Louis, prior to January 1, 1900, have run very close together so far as typhoid deaths are concerned, but since January 1, 1900, Boston has gone lower and St. Louis has increased.

(See Sedgwick's testimony, Vol. 3, pp. 2203-4-5, and 2239, 2250-1.)

At Vol. 3, page 2214, Prof. Sedgwick made the following statement:

"After a careful consideration of the subject I can say that, in my opinion, beyond a reasonable doubt, the principal portion of the annual increase of typhoid fever in St. Louis since January 1, 1900, has been due to the pollution of the water supply of St. Louis by the sewage of the Sanitary District of Chicago."

On cross-examination counsel for respondent undertook to and did qualify the witness as to what was his understanding of the term "beyond a reasonable doubt," as used by him in the above answer. Prof. Sedgwick had evidently given a careful study to the essentials in determining the source of infection as applied to the science of epidemiology, and in his experience had doubtless been led to accept only such evidence and to apply only such rules as would unquestionably lead to a discovery of the truth. In answer to the question propounded by counsel for the defendant, "What is a reasonable doubt,"

Prof. Sedgwick said:

161 "I have no objection to telling what I understand by the expression, 'beyond a reasonable doubt.' I mean by that an assurance of accuracy such as shall persuade me to the truth."

"Q. Do you understand that a reasonable doubt is one that must arise solely from the evidence adduced, and which excludes every other reasonable hypothesis from that of guilt?

"A. As I understand the question, that is my understanding of the conditions required."

(See Vol. 3, pp. 2214 and 2306; also 2292-3-4-5-6, 2358, 2381 and 2394.)

Gardner Williams, in speaking of the effect of the sewage of Chicago upon typhoid conditions in St. Louis, made this statement:

"I should say that the evidence afforded by the typhoid statistics of St. Louis for the period of 1895 to 1899, inclusive, was not ideal, but, nevertheless, would compare favorably with that of a large number of our American cities, and that, generally speaking, it would entitle the St. Louis water supply to rank in about the second class of water supply, as experts gen-

erally speak of them. Considering the evidence of the typhoid statistics of the city of St. Louis since the beginning of 1900, it appears that up to near the end of January the water supply of St. Louis during that month must have been about as good as formerly, but about that time there appears to have been a considerable infection of the supply, which has increased since each month, with the results that the typhoid statistics show the probable infection of the supply during 1900 to have been twice as great as the average between 1895 to 1899, inclusive, and that the rank of the water supply of St. Louis has materially dropped, as judged by the standard of sanitary purity. I have examined the records of typhoid fever in the cities on the Mississippi, Illinois and Missouri rivers, outside of the Sanitary District of Chicago. The Drainage Canal was opened on January 17, 1900. Basing my judgment upon the facts brought to light, the extensive examination of the conditions, it is my judgment that

to the discharge of sewage by the Sanitary District of Chi-
162 cago by means of the Drainage Canal, the Des Plaines and
the Illinois rivers, is attributable the major part of the increase of the typhoid fever as arrived at by the typhoid statistics of St. Louis since January 1, 1900, as compared with the period from 1895 to 1899, inclusive."

(See Williams' testimony, Vol. 3, pp. 2462-3.)

The testimony shows that since the opening of the Chicago Drainage Canal the water flowing into the Intake of the St. Louis Waterworks is unsuitable for domestic purposes, while prior to the opening of the drainage canal it was considered fairly good water; in fact, based upon the mortality record it may be said to have been a reasonably good water supply, while based upon the mortality record since the opening of the drainage canal as compared with conditions existing prior thereto,

and as compared with the mortality records of various other cities of similar size, it must now be classed as unwholesome water.

(See Teichmann's testimony, Vol. 2, pp. 1242-3-4-5-6.)

Based upon the analytical results it is shown that the water entering the intake in 1900 was more polluted than the water entering the intake in 1899, and that since there was no corresponding increased pollution in the Mississippi river above the mouth of the Illinois and no increase in the pollution of the Missouri river above its mouth, it must be taken as true that the increased pollution of the water going into the Intake tower was caused by and due to the increased pollution of the Illinois river in 1900 and since. It is also true that there was no real or substantial change in the physical condition of the Illinois river watershed during the period from 1899 to the present time save and except as to the addition of the sewage of the city of Chicago through and by means of the Chicago Drainage Canal.

(Teichmann's testimony, Vol. 2, p. 1245; Williams' testimony, Vol. 3, p. 2437.)

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17.

LONGEVITY OF BACILLUS TYPHOSUS OR TYPHOID BACILLI.

Since the discovery of Bacillus Typhosus as the cause of typhoid fever, professional investigators and sanitary scientists have employed every known and conceivable means of determining the exact duration of the life of this particular microorganism. After the most extensive and careful investigation it is yet unknown just how long the germ may live under the various conditions in nature. Sufficient information, however, has been obtained to know that much depends upon the resisting powers and individual strength of each particular bacillus.

It is pertinent to the issues in this case to know just how long it will be in the water of the Chicago Drainage Canal, the Illinois and Mississippi rivers. This is, according to all of the witnesses who testified in the case, after many series of determinations, a matter yet unknown. However, judging from the length of the life of the germ in laboratory experiments, we are able to reach a minimum limit of approximation, but under no circumstances can we reach the maximum limit. This depends largely upon the resisting force of the germ, its vital powers and the condition of the water into which it is discharged.

Dr. Ravold in this connection made some very valuable experiments as to the life of the germ in the sterilized, the distilled, and the natural waters of the rivers in question.

These experiments were made continuously from June to September, 1902. During which period work was constantly and continuously done for the purpose of determining sufficient information and knowledge upon which to base a definite con-

clusion as to its longevity in these waters. The examinations were made under almost every conceivable manner practicable in laboratory work.

In the unsterilized living water of the Mississippi river at St. Louis he found the germ would live from eight to twenty-one days. In sterilized water (boiled to such temperature 164 as was sufficient to kill all germ life contained in it) it was found that the germ of this disease lived from twenty-five to sixty days.

The foregoing experiments were made with the samples of water containing the bacilli typhosus, suspended in an open window exposed to the sunlight during the entire day. Similar experiments were made with the samples of water enclosed in total darkness, with results practically the same.

(Dr. Ravold's testimony, printed record, Volume 1, page 49.)

During the period above mentioned, the following results in sterilized, distilled and natural water were obtained by Dr. Ravold in his experiments as to the longevity of this particular micro-organism.

The Mississippi river at Grafton, in total darkness, 10 degrees Centigrade or fifty degrees Fahrenheit, it lived 59 days.

First culture 40 days, C culture and B culture not recorded.

The testimony of Dr. Ravold shows that these experiments were made with three cultures, known as A, B and C.

Again under similar circumstances A culture was found to live 51 days, B culture 25 days and C culture 22 days.

In sterilized water, taken from the Chicago Drainage Canal at Lockport, kept in total darkness, at ten degrees Centigrade or fifty degrees Fahrenheit, this bacillus lived:

A culture 45 days, B culture not recorded, C culture 22 days.

In sterilized water of the Missouri river, collected at Fort

Bellefontaine, kept in total darkness at ten degrees Centigrade or fifty degrees Fahrenheit,

A culture lived 59 days, B culture 57 days and C culture 57 days.

In sterilized Mississippi river water collected at the Intake, Chain of Rocks, St. Louis Waterworks, kept in total darkness, at ten degrees Centigrade or fifty degrees Fahrenheit,

A culture lived 59 days, B culture 59 days and C culture 34 days.

IN DISTILLED WATER.

Kept in total darkness at 20 degrees Centigrade or sixty-eight degrees Fahrenheit,

165 A culture lived 22 days, B culture 54 days and C culture 30 days.

Distilled Mississippi river water collected above Grafton, kept in total darkness at 20 degrees Centigrade or 68 degrees Fahrenheit,

A culture not recorded, C culture not recorded, and B culture lived 37 days.

In distilled water collected from the Drainage Canal at Lockport, Illinois, kept in total darkness at twenty degrees Centigrade or sixty-eight degrees Fahrenheit,

A culture lived 54 days and B culture lived 54 days.

In distilled Missouri river water collected at Fort Bellefontaine, kept in total darkness, at twenty degrees Centigrade or sixty-eight degrees Fahrenheit,

A culture lived 57 days, the other two cultures not being recorded.

In distilled Mississippi river water collected at the Intake of the St. Louis water supply, kept in total darkness at twenty degrees Centigrade or sixty-eight degrees Fahrenheit,

A culture lived 54 days, B culture 55 days and C culture 54 days.

Distilled water kept in the open window, facing the east with the sun shining upon it the entire forenoon of each day, with 100 cubic centimeters of water contained in the bottle.

A culture lived 22 days, B culture 22 days and C culture 45 days.

These experiments taking place in July, August and September of 1900.

The following, under similar conditions, of water collected from the Mississippi river above Grafton,

B culture lived 45 days, C culture 60 days.

Distilled water taken from the Drainage Canal at Lockport,

A culture lived 40 days, B culture lived 31 days and C culture lived 22 days.

Mississippi river water, Intake Tower,

B culture lived 46 days, C culture 45 days, A culture still living at the end of 65 days.

166 A series of experiments were conducted by Dr. Ravold in June, July and August, 1901, for the purpose of determining the length of the life of the bacilli typhosus, in the samples of living water from the Chicago river, Chicago Drainage Canal at Lockport, Illinois, the Illinois river at Peoria, and the Mississippi river at the Intake.

Samples of water were collected at different times from the above named points and 200 cubic centimeters poured into sterilized Erlemeyer flasks and corked with cotton stoppers. Some were exposed to the sunlight, others kept in darkness at a temperature of 16 degrees Centigrade or 60.8 Fahrenheit. Those exposed to sunlight were placed on a shelf in a window, facing south, and the direct rays of the sun impinged full upon the western flask in the window at 10:45 a. m., and left the flask

furtherest east at 2:15. The total time of exposures to the sunlight daily being about three hours. The samples of all water used in conducting these experiments being turbid.

A record was kept showing the hours of sunlight on the respective days during which the determinations were made, together with a record of the temperature of the atmosphere in the window where the samples were kept.

(Dr. Ravold's testimony, printed record, Volume 1, page 472.)

The typhoid culture used in these experiments were,

No. 1 received from Dr. Westbrook of the University of Minnesota, said to be found by him in the waters of the Mississippi river at Minneapolis.

No. 2 came from the spleen, sent in by Dr. C. G. Kirchner from a patient dead of typhoid fever at the City Hospital, St. Louis, and separated out in the laboratory June 8, 1902.

It will be noticed that the result of the two cultures are practically the same.

In the window the following results were obtained:

Water collected from the Drainage Canal, Western Avenue, Chicago, June 13th, typhoid bacilli lived five days.

Water collected July 15th, 7 days.

167 In water collected from the Drainage Canal at Lockport, June 13th, typhoid bacilli lived 4 days.

July 5th, 8 days.

In samples of water collected from the Illinois river above Peoria, June 13th, typhoid bacilli lived 5 days.

July 5th, 10 days.

July 11th, 8 days.

Water collected from Illinois river, Pekin Bridge, June 13th, typhoid bacilli lived 4 days.

June 5th, 10 days.

Water collected from Chicago river, Adams street, June 13th, typhoid bacilli lived 4 days.

In the laboratory the following results were obtained:

From water collected from Chicago river, Adams street. On the 16th day the bacillus was still alive.

Water collected from Chicago Drainage Canal, Western Avenue, at 16 degrees Centigrade, typhoid bacilli lived 7 days.

July 5th, 8 days.

Water collected from Drainage Canal, Lockport, July 15th, 10 days.

Water collected from Drainage Canal above controlling works, Lockport, June 13th, lived 9 days.

Illinois river above Peoria, June 13th lived 10 days.

July 5th, 21 days.

July 17th, 16 days.

Chicago river, Adams street, June 13th, this bacillus lived 4 days.

July 5th, 7 days.

Tap in the laboratory in St. Louis, June 13th, lived 12 days.

Chicago river, Adams street, July 5th, lived 23 days.

Drainage Canal at Lockport, July 17th, lived 11 days.

Drainage Canal, Jackson street, Joliet, July 17th, lived 13 days.

Illinois river, Pekin Bridge, July 17th, lived 16 days.

Dr. Ravold in this connection showed that with reference to experiments in the sunlight typhoid bacillus lived on an average of five days in natural water collected from the Illinois and Michigan Canal at Lockport.

168 In water collected from the Drainage Canal, Western Avenue, Chicago, the average life in the window was six days, in the refrigerator 7 1-2 days.

In water collected from the Drainage Canal at Lockport the average life of this bacillus in the window was 4 3-4 days, in the refrigerator 10 2-3 days.

In water collected from the Drainage Canal, above the controlling works, Lockport, the average number of days in the refrigerator was 9.

From samples of water collected from the Drainage Canal, Jackson street, Joliet, the average number of days alive in the window was 9, in the refrigerator was 13.

From samples of water collected from the Illinois river above Peoria, the average number of days alive in the window was 7 2-3 days, in the refrigerator 11 1-2 days.

From samples of water collected from Illinois river at Pekin the average number of days alive in the window was 7, the average number in the refrigerator 15.

From samples of water collected from the Chicago river at Adams street, the average life of this germ in the window was 4 days, in the refrigerator 5 1-2 days.

In water collected from the tap in the laboratory, St. Louis, the average life in the window was 7 days, in the refrigerator 12 days.

(Dr. Ravold's testimony, printed record, Volume 1, pages 468-476, inc.)

The testimony of Dr. Ravold on the longevity of the typhoid micro-organism is substantially as follows:

It is impossible to carry out in a laboratory experiment the condition which obtain in a running stream. In living water in a flask in the laboratory experiment the bacteria are in evidence, each of which produces a particular toxin, so that in a very short time the toxines produced by the micro-organisms that are at work seem to act unfavorably upon the typhoid bacil-

lus placed in the water. In sterilized water the typhoid lived quite a number of days longer than in the natural water.

169 In a running stream the typhoid micro-organism is not subjected to the poison produced by other bacteria to the same extent as in the stagnant water in the flask. In the running stream it would not be confined to a given water, because it can swim about and be carried along by the running water. Its chances in living, running water would, therefore, be vastly greater than in the flasks.

The micro-organism is not known to multiply in the water of a river into which it is discharged. It remains dormant until its life history is over, unless in the meanwhile it reaches a favorable condition for growth and multiplication.

It is not known that the death of the typhoid bacillus is due to the toxins produced by the bacteriological conditions of its life and the causes of its death in running water are not definitely known. In fact, it is impossible under the science of bacteriology, as it exists today, to definitely ascertain its longevity in the various conditions of nature in which it is known to exist.

(Dr. Ravold's testimony, printed record, Volume 1, pages 478-479-480.)

It is impossible to determine the absolute longevity of typhoid bacillus in running water, because the conditions which obtain in a stream cannot be produced in the laboratory experiments, and to put living typhoid bacilli in water that is used for drinking purposes would be murder. So, therefore, no experiment can be made in a living stream. The conditions in the water are these: The toxins or product produced by water bacteria that may or may not be deleterious to the typhoid bacillus would be greatly diluted by the flowing water. Typhoid bacil-

lus is a mover, and can swim out of the way of any thing that would be deleterious to it in a river. The fact that it is motile is the reason it can exist in the water of a river highly charged with sewerage. It has motility and can move away from the deleterious products or substances contained in the water. In laboratory experiments it is confined and therefore unable to prolong its life.

(Dr. Ravold's testimony, printed record, Volume 1, pages 790-791-792.)

170 It was scientifically determined by the Massachusetts State Board of Health that a typhoid bacillus lives in the waters of the Merrimac river for twenty-five days. These experiments were made at Lawrence and Lowell, Massachusetts.

(Dr. Ravold's testimony, printed record, Volume 1, page 50.)

It is not affected by freezing and will, therefore, live in ice. If discharged into the Illinois and Mississippi rivers and those rivers should, within the life of the germ, become frozen over with ice, the germs contained in the ice would not be thereby destroyed, but would live in a dormant condition until the ice disappeared and then until they had run their natural time or duration of life.

The sunlight has some effect on them, it shortens their life to a limited extent. However, as a general proposition, the belief among some that they are entirely killed by the sunlight is now known to be a myth; it is not true.

In a stream they naturally seek the darker regions of the water, and for that reason are affected by the light to a very slight extent. The sunlight would not affect them to a greater depth than one foot in the Illinois river. The result is they

would descend to and travel in the more rapid portion of the stream.

(Dr. Ravold's testimony, printed record, Volume 1, pages 797-798-799.)

They have been known to exist in soil for a considerable time, and to be discharged from a person sick of the disease for a period of 8 to 18 years after recovery.

(Dr. Ravold's testimony, printed record, Volume 1, page 790.)

Dr. Ravold in this testimony further stated that typhoid bacilli would live for a long time in a moist earth, as a number of experiments have shown this to be true. Experiments by Firth and Horniks show that these micro-organisms live a long time in earth and sand that is moist and retain their virulency. That it has been known to live 25 days in dry earth and longer than that in moist earth. The above named experts carried out a series of experiments and were able to capture the typhoid bacillus in the dust by blowing across the typhoid infected earth.

171

The dredging at Detroit, Michigan, show that the germ lived a great length of time in the mud and filth of lakes and rivers, and after being stirred up retain their virulence and spread the disease.

(Dr. Ravold's testimony, printed record, Volume 1, pages 953-954.)

Typhoid fever germs will live in sewage polluted waters, such as are found in streams, reservoirs and the like, for a period of weeks and months. (Fuller's testimony, Vol. 3, pp. 2617-18. Sedgwick's testimony, Vol. 3, p. 2314. Fuller's testimony on cross-examination, Vol. 3, pp. 2628-9. Fuller's cross-

examination, Vol. 3, pp. 2664-5; also, Fuller's testimony, Vol. 3, pp. 2626-2627. Sedgwick's testimony, Vol. 3, pp. 2207 and 2765.)

Mr. Rudolph Hering, the defendants' witness, on cross-examination, was asked these questions:

"Q. Generally speaking, Mr. Hering, taking all the observations of bacteriologists and sanitary scientists the world over, what in your opinion is the longevity of pathogenic bacteria coming from the sewers of a city when discharged into a running stream?

"A. I consider that every disease bacterium has presumably a different length of life under the same conditions, and presumably also under the different conditions, and as I have not studied concerning any other bacteria than the typhoid bacillus I could not make such a general answer.

"Q. Mr. Hering, is there any instance in your whole career as a sanitary engineer, or an instance coming under your observation as to the work of other reputable sanitary engineers or sanitary scientists where the water in a running stream has been recommended as free from the typhoid bacilli of a large and populous city existing on that whatershed with a stream velocity of from ten to twenty days?

172 "A. Without filtration, I do not know of any case exactly answering your description."

Hiram F. Mills, for several years connected with the Massachusetts State Board of Health, conducted a series of observations as to the longevity of typhoid fever germs in the water of the Merrimac river. He found them to decrease rapidly in numbers from 1 to 25 days, and, based upon these determinations arrived at by Mr. Mills, Mr. Hering testified as follows:

"Q. The table prepared by you, or used by you, rather,

giving the results of the experiments of Hiram F. Mills on the longevity of the typhoid germ is the one that you have heretofore used in your experiments and work as a sanitary engineer?

"A. Whenever I was called upon to consider the question of longevity of the typhoid bacillus I have had those Massachusetts experiments in mind." (Hering's testimony, Vol 8, pp. 7026-7-9.)

In determining the longevity of typhoid fever germs, there is nothing in the sanitary science that permits an exact formula for the purpose of determining the life of the germ, so far as time limit is concerned, or, in other words, so far as the time required for the water to pass from the source of the deposit of the infected material to a given point in the stream. No such formula can be adopted, because it would not be wise or feasible in the present stage of sanitary science to attempt to advance the same, in as much as it contains certain elements which compel it to be considered as an individual case. The character of the specific microbe and the temperature of the water would certainly have to be considered and would certainly have some influence upon the period of longevity. The volume of water, the amount of dilution, the temperature of the atmosphere and the water would of necessity have to be considered. (Jordan's testimony, Vol. 7, pp. 6355-7-8.)

In reference to the experiments that have been made during the last fifteen or twenty years by different bacteriologists for the purpose of determining the data of longevity of typhoid bacilli, different methods have been used, and under these
173 various determinations the life of the typhoid bacillus has been reported to vary widely. They have been known to live in sterilized water taken from Lake Michigan as long as 93 days. It is, however, a well known and undisputed fact by bacteriolo-

gists and sanitarians that typhoid fever germs live in river water for a considerable period or length of time, varying upon the extent of the pollution, the character of the water, the temperature and the opportunities for sedimentation, and, therefore, there is a gradual dying out in the bottom of the stream. Giving special resistant forces and the vitalizing powers of each individual germ, in his experiments conducted by the use of the parchment and celluodin sacs, Prof. Russell, in Vol. 7, p. 6512, found that in the waters of the Illinois river at Averyville, typhoid bacilli lived while contained in the sacs for a period of nine days. The following results are found to have been obtained:

On the third day 44 colonies were removed, of which 14 were found to be typhoid. These 44 colonies were taken from five sacs, and the typhoid organisms were found in three out of the five.

On the ninth day, two colonies were taken from two sacs, one colony of which proved to be typhoid.

So, with the limited number of experiments carried on by Prof. Russell, it will be observed that typhoid bacilli lived in this unnatural condition in the waters of the river at Averyville for a period of nine days. (See Russell's testimony, Vol. 6, pp. 6512-13.)

In this connection, we call attention to the fact that conditions in the parchment and cellodin sacs did not assimilate the actual conditions in the stream. This question was propounded to Prof. Sedgwick.

The following statements were made by Prof. Russell in his cross-examination:

"Q. Taking into consideration the care and precaution that was used by you in making the determinations contained in the tables which you read in advance, in your direct testimony, and

assuming that typhoid fever dejecta is deposited in a running stream which flows for a period of nine days, at which
174 point the inhabitants of a city receive their water supply, and knowing that you had observed the presence of the typhoid bacilli during the series of examinations which you made in the water at that point—assuming the bacterial contents of that water to remain or be practically as contained in the sacs with which the observations were made, would you recommend that water as free from typhoid bacilli, and therefore suitable for domestic and drinking purposes?

"A. Taking into consideration the fact that typhoid organisms deposited in running streams would not be subject under natural conditions to such conditions as outlined in the foregoing question, for the reason that in such flow there are factors operative and always operative which are not assumed in the foregoing question, and which must be assumed if the conditions are made to refer to conditions that actually do obtain in a flowing stream, and taking into consideration all the knowledge which I possess from a bacteriological analysis of waters so exposed and the conditions which are referred to, it is my belief that waters discharged into a stream, the character of which corresponded to the conditions which are assumed in the question, but which under such conditions are affected by these other factors which are always operative, it is my opinion that typhoid organisms would not be found in such waters when a period of flow was of nine days' duration.

"Q. But, assuming aside from the natural conditions that the water remained in the river as it remained in the sacs for nine consecutive days, and in the ninth day you found typhoid bacilli present, as shown in your observations, would you consider that water as being free from typhoid bacilli at the end of the ninth day?

"A. It would be impossible to base a recommendation of such a character unless all the facts which bear upon this question were taken into consideration, and if those facts were in accordance with the facts as represented in the experiment referred to in which analyses were made in large numbers and at daily intervals, and in which out of this series of analyses the typhoid organism was found abundantly the first day, the second and the third day, but was not found at any subsequent
175 date, although frequent daily examinations were made, except in one solitary instance, on the ninth day, and was found in no instance thereafter, although examinations were continued for double this length of time, I should under these circumstances consider that I was warranted in assuming that the typhoid organisms introduced in such water would have disappeared so completely that under no conditions would the water have been able to produce disease if it had been consumed by human beings.

"Q. And under the facts assumed, and at the end of the ninth day, you would recommend to the people that they could drink that water with impunity so far as the effects of the typhoid fever germs were concerned?

"A. The recommendation as to whether a water supply is pure or suitable for domestic use presupposes conditions which are not assumed in the foregoing question and which must of necessity be taken into consideration before any such recommendation can be made, and a water supply which is known to contain typhoid bacilli must, therefore, be subjected to exceedingly stringent examination before one would be warranted in making any such recommendation as indicated in the question.

"Q. Do you mean a stringent examination for the purpose of determining the presence or non-presence of typhoid bacilli?

"A. I do.

"Q. Do you consider the observations and examinations which you made of the water contained in the sacs, as shown in your tables, to be a stringent examination of that water, for the purpose of detecting the presence or non-presence of typhoid bacilli?

"A. I consider that the examinations which were made of the analysis of this water were sufficiently stringent to have detected the presence of the typhoid bacilli if such had been present.

"Q. Then under the conditions assumed in the preceding question that if the water in a running stream ran nine days was during the time in the same bacterial condition as the water contained in the sacs which were used in your experiments, and underwent the same bacterial changes, containing typhoid bacilli which also underwent the same changes, that water would
176 be suitable for drinking purposes at the end of the ninth day and at the place reached at the end of the ninth day?

"A. The conditions which were stated in the assumptions named in the question are so entirely foreign to what do exist when waters find their way in a flowing stream that a comparison which is made between the conditions of this experiment and the conditions which would occur when typhoid organisms were deposited in a running stream for nine days' flow, are such that I am unable to state exactly what would occur under the conditions assumed, but when I take into consideration the fact that in a case of water containing approximately 5,400,000 typhoid bacteria in a given volume, that an exposure of that water under the conditions as described in the foregoing answers failed to reveal the presence of typhoid organisms in all but one case out of the entire number examined on the ninth day, so that the vitality of this enormous number of organisms had been entirely lost with the exception of the single germ referred to,

except in the case of the first three days, when typhoid organisms were demonstrated, I should consider that a conclusion which is based upon the results which were obtained in the case of this single organism alone and not the whole of the results of the experiment are not proper as indicating what the condition of affairs would be which would occur in nature."

(Russel's testimony, Vol. 7, pp. 6600 to 6602, inclusive.)

Prof. Mason, one of the defendants' witnesses, on cross-examination, made the following statement with reference to the life of typhoid germs:

"My opinion is that in consideration of the facts regarding the Chicago sewage being dumped into the Illinois river, as at present, and the facts concerning the conditions of the Illinois river, that the germs of typhoid fever coming from Chicago sewers would be destroyed en masse by the time the mouth of the Illinois was reached, although some resistant organisms might go beyond that point, such organisms, however, representing a small number, and in my opinion low vitality. My opinion is that the longevity of the typhoid germ depends in the first place upon its parentage, but in the second place
177 it depends upon the conditions under which the germ is grown, and the conditions with which it finds itself surrounded. In the same way, an individual may come from a healthy parentage and live in a healthy form, but because of conditions surrounding that individual, his vitality may be greatly lowered. Just so with the typhoid germ. Should it struggle, for instance, over periods of time it will lose, in my opinion, the vigor of its life, and be incapable of producing its normal amount of poison. My reason for this belief is, as I have already shown in my direct testimony, that there seems

to be a great loss in poisoning power of the germ when the period of time is lengthened between the point of infection of a water and the point of time when such water is drunk. It is a fact that the typhoid fever germs from some typhoid fever patients are possessed of a greater vitality than the germs from other typhoid fever patients. This is true with reference to pathogenic germs in general, for the same reason that a crop of turnips grown upon a good soil would be better than grown one upon a poor. My opinion is that it will be impossible to tell what shall be the longevity of specially resistant cells. Experimental data have shown that for the general mass the longevity is fairly well fixed, so that a good deal of knowledge has been obtained with reference to the average germ, although we are still in ignorance as to the longevity of specially resistant individuals. It is my opinion that these specially resistant cells at their point of departure from the human body are fully as capable or even more fully capable of producing disease than the greater numbers of their less resistant brethren, with whom they start upon their journey, after leaving the body. Whether they arrive, after the interval that may be chosen for the period of investigation, in a condition to produce disease, may be open to question, because the mere fact of their being resistant enough to arrive living does not mean that they will have enough toxin producing powers left to form that serious poison which may cause disease. This, however, is a matter of speculation. (Mason's testimony, Vol. 7, pp. 6960-1-2.)

In his cross-examination, Dr. Barker said in response to a
178 question as to how long typhoid fever germs would live in ordinary river water:

"Well, I should think it would be only a case which would be mere opinion; I should think they would, or might, live as long as ten days. I don't think they would live as long as thirty days." (Barker's testimony, Vol. 8, p. 7167.)

Dr. Barker, in his cross-examination, in Vol. 8, page 7131, testified as follows:

"Q. Do you mean to class yourself as an epidemiologist when you say that the typhoid fever germs will live in the Missouri, the Mississippi and the Illinois river only from five to seven days?

"A. I do not say that. I didn't say that they had lived in those rivers only from five to seven days.

"Q. How long would you say they would live?

"A. I did not say how long they would live.

"Q. How long will they live?

"A. I do not know, nor is there any way at present of finding out." (Barker's cross-examination, Vol. 8, pp. 7131-34-35.)

Mr. Hill, one of the defendants' witnesses, made personal observations as to longevity of typhoid fever germs in the waters of the Delaware river, and found their life history to be limited to from five to eight days. Determinations were also made with reference to the longevity of the germs in the waters of the Schuylkill, a more polluted stream than the water of the Illinois river. From these experiments they were shown to have been alive up to a period of eight days, and, based upon these experiments, Mr. Hill expressed it as his opinion that the life of the typhoid organisms in sewage polluted water under normal conditions which prevail in the majority of the rivers of the United States to be placed at from five to eight days. (See Hill's testimony, Vol. 8, pp. 7509-16-17-18.)

Several experiments were made by Professors Jordan, Zeit and Russell for the purpose of determining, if possible, the longevity of typhoid fever germs in the Chicago river, the
179 drainage canal and the Illinois river. These experiments, as heretofore stated, were made by means of parchment

and cellodin sacs. The water from the stream was placed in the sacs, and to this was added a large number of typhoid bacilli. The sacs were then suspended in a running stream and from day to day samples were taken from the streams and examined for the purpose of determining if typhoid bacilli could be discovered therein. In the waters of the Drainage Canal Prof. Jourdan discovered three typhoid bacilli from 37 colonies picked from the plate used, one cubic centimetre of water being plated, the water of the drainage canal having been contained in the sac suspended in the water for a period of ten days. (See Jourdan's testimony, Vol. 7, pp. 6198 to 6239, inc.)

At page 6239 of the record, Prof. Jourdan, speaking of the longevity of typhoid bacilli, made the following statement:

"Remembering that the upper stretches of the Illinois river are highly polluted with sewage, and that considerable additions of sewage are made to the Illinois river at points along its course, I do not believe that bacilli introduced into the Des Plaines or upper portion of the Illinois river would live under natural conditions more than five or six days."

Prof. Jourdan, at Vol. 7, page 6276, further says:

"It is of course well recognized that in rural communities a longer period may elapse after the discharge of typhoid bacilli from the bodies of typhoid patients before the bacilli enter water courses, than is the case with such discharges in an urban community furnished with a sewage system. It is also well known that typhoid bacilli in the infections or infectious discharges from the bodies of typhoid patients, when emptied into a loosely constructed privy vault or outhouse, may retain their vitality and virulence for a long period. Such was the case in the Plymouth epidemic, already cited.

"Typhoid bacilli have been known to retain their vitality for upwards of five months in the contents of privy vaults. It is evident that if the contents of such vaults or outhouses be washed down into a stream by heavy rains or melting snows, or if the contents of such vaults be spread as manure upon fields near the banks of a river or other stream, the bacilli may find their way into the water course."

And it has been shown that typhoid bacilli will live longer in relatively pure water in the presence of a relatively small amount of organic matter than in polluted water charged with the sewage of a great city.

So it seems they do live for at least a period of from ten to twenty days with strongly vitalized organisms surviving a very extensive and uncertain time in the waters of a polluted stream.

Experiments upon the longevity of the typhoid bacillus have been made in the laboratory where the question of motion, sunlight and air were taken into account, and it was found that it varied from a period of some weeks to some months. (Whipple, cross-examination, pages 2081-2.)

In reference to the longevity of typhoid fever germs in connection with sewage polluted water, Prof. Sedgwick said:

"Here also my ideas have undergone some change in late years. Broadly speaking, the tendency has been to come to the belief, or has been to show or to indicate greater longevity. Laboratory experiments have sometimes indicated short and sometimes longer longevity. Practical experience has tended to make us believe in greater longevity than that formerly entertained. I have reference to the various conditions in streams. My belief is that in sewage polluted streams, typhoid germs might live in gradually diminishing numbers for weeks, months or

even years. I consider that, even though the number of colon bacilli be shown by occasional tests in the water of the Illinois river to be no higher today than they were before the opening of the drainage canal, the mere fact that the addition of vast population contributing sewage to the Illinois river constitutes and must always constitute an added menace to the health of people using the water of the Illinois river at its mouth or below it, and I may add that I have this opinion, or I will say for the reason that bacteriological examination cannot always be made

at the very moment or at all times and seasons of the year
181 and are at best not absolute guides as to the sanitary condition of the water, there might be times and seasons when the material would flow by escaping analysis and pass on and do harm to the people below. Assuming that the germs of typhoid fever come from the sewers of Chicago, and pass by way of the drainage canal and Lake Peoria, large numbers of them might be deposited in the bed of Lake Peoria for the period of months, and if so deposited would not be entirely destroyed at the end of that time. If the accumulation of typhoid fever germs is formed in slack water basins of the Illinois river, which might be true especially in the case of a large amount of typhoid fever in Chicago, they would result in a storage there of a vast number of germs, and a sudden flood would sweep them out and bring about such conditions that more typhoid germs would be flowing in that stream than in the drainage canal itself. I know of an excellent instance in a stream, and I think there have been some in lakes, some cases of that sort in lakes or sluggish bodies of water. The best example we have of such an effect on streams, and it happens to be one accompanied with slack water, so we have the double demonstration in one case, and that is the well known case of typhoid fever in Detroit resulting from the dredg-

ing of Black river at Port Huron, which caused the carrying of the detached sediment down the St. Clair river and through St. Clair lake and into the intake of the Detroit waterworks. That was in 1892, and is probably the most striking case we have on record. It was very thoroughly investigated, and I am familiar with the data on which the conclusions were based, and in my opinion it was a well established case, and is the best that I know of. (Sedgwick's Testimony, Vol. 3, pages 2197-8-9.)

A striking instance of the life of typhoid bacilli in sewage polluted water is found in the case of the epidemic of typhoid at Lawrence, described by Prof. Sedgwick, as follows:

"The mouth of the Lowell sewers is about nine miles above the intake of the Lawrence waterworks. From that point the water was pumped to the reservoir of the city of Lawrence, and in that reservior *was kept for a period varying from one to more than two weeks. If we add to this one or two weeks the time spent in flowing the nine miles and through the pump*
182 *which I suppose, or which I know from observation, would be a short time, we may say the period was some time probably as long as fourteen days or more for that amount of the storage proved to be some protection undoubtedly to the people in Lawrence, but an inadequate protection, because they suffered relatively more from typhoid fever than the people of Lowell did, although they were not so near the sewers as Lowell.* I may add that the difference between the Lowell and Lawrence reservoirs was very striking and very interesting. The Lowell reservoirs were so arranged that the water passed in and out almost immediately, and the number of bacteria in the Lowell water was sometimes quite high, because of this absence of adequate storage. *In Lawrence the storage was longer,* and was undoubtedly protection of a certain sort, a certain imperfect

sort, to the people of Lawrence, but it did not protect them adequately or perfectly. The difference of infection of course was immense. Lowell received the germs from Stony Brook, and Lawrence received those same germs, all that Lowell had not taken out, and in addition the germs from upwards of 1,000 cases in Lowell, and we say the storage was a certain protection, but the mortality was considerably higher in Lawrence than it was in Lowell. (Vol. 3, pages 2237-2238.)"

Covington, Kentucky, and New Albany, Indiana, are well known instances of these retentive life powers of typhoid fever germs. At Covington, Kentucky, the water of the Ohio river, more or less polluted from the streams above, is kept as long as thirty-two days, and yet the city suffers severely from typhoid fever, apparently due to infected water.

At New Albany, Indiana, on the same stream, the storage is about a month in sedimentation basins, but typhoid fever is high in New Albany, showing conclusively that storage for a period of even as long as a month cannot be depended upon to remove typhoid germs. (Sedgwick's testimony, Vol. 3, page 2238.)

At Zurich, Switzerland, a typhoid epidemic was clearly traced to the stirring up of sediment near a broken intake pipe.

There is an abundance of evidence showing the prolonga-
183 tion of life of the typhoid germs in sediment and highly polluted waters, and reasoning from analogy from the general behavior of bacteria and largely from epidemiological evidence carefully and systematically presented, and from the fact that freshets are apt to cause and do cause epidemics of typhoid fever in communities using water derived therefrom, and with the contemporaneous occurrence of the epidemic which would explain such increase of epidemic, in streams existing

above, we are led to the unalterable conclusion that heaps of material at the mouths of sewers, or in running streams, when stirred up, cause epidemics of typhoid fever. (Sedgwick's testimony, Vol. 3, pages 2310, 11, 12 and 13. Williams' Testimony, Vol. 3, pages 2444-5; 2458-9.)

18.

THE VELOCITY OF THE ILLINOIS RIVER WATER, OR THE TIME IN WHICH IT TRAVELS FROM CHICAGO TO ST. LOUIS.

It is necessary to know approximately the time required for water to pass from Chicago to St. Louis in order to determine whether or not typhoid fever germs and other pathogenic bacteria will pass from Chicago to St. Louis alive and virulent. For the purposes of this investigation Prof. Van. Ornum, of Washington University, was requested to make and did make a scientific determination of the velocity of the stream from Lake Michigan to St. Louis, beginning at Chicago, passing through the Chicago river, the drainage canal, down the Des Plaines river, and Illinois river and Mississippi to the Chain of Rocks. This experiment was made in March, 1903, at a time, it is true, when the water in the river was reasonably high. This experiment was made by means of floats specially prepared for the purpose, which met with the least possible resistance during the journey. It was found that the time required for water to pass from Lockport, opposite the Bear Trap dam, to the intake at Chain of Rocks, St. Louis, was nine full days and three minutes, which, added to thirty-four hours and twenty-six minutes, required to pass through the drainage canal from the
184 South Branch of the Chicago river to opposite the intake at the Chain of Rocks, complete the full journey in 10 days, 10 hours and 29 minutes. When the floats came down the Mississippi river, it will be observed from the demonstration of Prof. Van Ornum, that the wind was blowing (if any possible effect could be produced) so as to carry them up stream, and

regardless of this fact each of the three floats deposited in the Illinois river at Grafton passed down the Mississippi over to the western side and between the intake of the St. Louis waterworks and Missouri shore. (See Van Ornum's testimony, Vol. 2, pp. 1724 to 1746; and also Complainant's Exhibit 40.)

These experiments were carried on by Prof. Van Ornum, together with the assistance of Mr. C. V. Mersereau, Frank J. Brown, J. E. Gibson and T. F. Reed, whose testimony will be found in Vol. 2 from pages 1793 to 1835, inclusive. In this connection Mr. Williams made a careful estimate of the time required for water to travel from Lakeport to the intake of the St. Louis waterworks, based on the guages of the Illinois river, together with the flow of the river from Chicago to St. Louis considering it at these various points. He found under the conditions which existed since the opening of the drainage canal that the waters of the drainage canal, something over three hundred days in a year, would reach the intake of the St. Louis waterworks in from nine to fifteen days from the time it left the Bear Trap dam; that a portion of the infection contributed or water added might be delayed considerably beyond this time, but that he was quite certain that most of the mixed water and sewage of Chicago would reach the Mississippi river at the Chain of Rocks within the period above mentioned.

(See Williams' testimony, Vol. 3, pp. 2434, 2437-38.)

Albert S. Crane, the defendant's witness, testified, after qualifying, that he had prepared the chart introduced into evidence by this witness, Mr. Hering, which will be found on page 7001 of the printed record, under the caption, "Sanitary District of Chicago, Schematic representation of the self-purification of the waters of the Missouri, Mississippi and Illinois rivers between the points indicated, based upon the length of life

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of the typhoid bacillus, as fixed by experiments made under the direction of Hiram F. Mills," the results of which will be found under the heading of the paper entitled "Typhoid fever in its relation to sewage supply." This chart was made under the direction of Mr. Hering, one of the defendant's principal witnesses, and a gentleman who was the chairman of a commission which recommended the construction of the Chicago Drainage Canal. The data for the profiles, including the Mississippi, the Missouri and the Illinois rivers, were taken from a paper published by the Department of the Interior, entitled "Water Supply and Pollution," General Survey No. 44. These figures were used entirely in the profiles, except on the upper part of the Illinois river where other figures were taken in order to make the profile more in detail. These latter figures were taken from a report made by Lyman E. Cooley, entitled "Waterway from the Lakes to the Gulf." In this the distance from the mouth of the Illinois river at Grafton to St. Louis is calculated at 38 miles, and from the mouth of the Illinois river at Grafton to the upper dam at Joliet is fixed at 325 miles, while the distance from dam No. 1 at Joliet to Lake Michigan is given at 38½ miles. The actual time of flow as representing the minimum time has been corrected for mean time of flow. The mean time flow was taken as .8 of the minimum. Fifteen days was given as the shortest time that the floats in the test carried on, under the supervision of Mr. Rudolph and Mr. Crane, would pass from Chicago to St. Louis, which under the corrected time, is determined at 18½ days. The velocity of the Mississippi and Missouri was computed, first, by the mean discharges of the two streams, on the Mississippi at Grafton and on the Missouri river at St. Louis. They were found to be 57,000 and 120,000 cubic feet per minute, respectively. The data with reference to the flow of the Mississippi and the Missouri were obtained by using the reports of

the Mississippi River Commission, entitled "Tabulated results of discharge measurements of the Mississippi river and its tributaries and outlets for the years 1838 to 1898," and plotting these to form a discharge curve. In the case of the Mississippi river,

186 the average gauge readings at Grafton were taken for the years 1890 to 1894, inclusive, and then for the Missouri river the years 1895 to 1899, inclusive. After these average stages were obtained the average discharge was obtained directly from the curve. The chart showing the curve of the respective rivers will be found at page 7011 of the record. In the tabulated results of the Mississippi river above referred to are found a large number of discharge measurements, together with the gauge readings, mean and maximum depth, width of the river and velocity in feet per second. The discharges at the various towns along the river are also computed, and by looking in the table the velocity at these towns or a part of them will be found. The velocity of the river between these towns is taken as the velocity at the gauging stations and the time computed by using the velocity and the distance. This course was pursued for both the Mississippi and the Missouri rivers. The curves were obtained by using the data obtained by the Massachusetts State Board of Health and published in a report of the State Board of Health of Massachusetts, entitled "Typhoid fever in its relation to water supply, by Hiram F. Mills." The results there given were embodied in a curve and from the curve the following is deduced:

100 per cent of the bacteria were living on the first day.
73.4 per cent of the bacteria were living on the third.
50.8 per cent of the bacteria were living on the fifth.
30.8 per cent of the bacteria were living on the seventh.
14.1 per cent of the bacteria were living on the ninth.
5.2 per cent of the bacteria were living on the eleventh.

2.5 per cent of the bacteria were living on the thirteenth.

1.6 per cent of the bacteria were living on the fifteenth.

1.0 per cent of the bacteria were living on the seventeenth.

0.4 per cent of the bacteria were living on the nineteenth.

Assuming that the number of typhoid bacilli contributed was proportional to the population, the curves were started at the extreme from St. Louis. Working towards St. Louis, the results for the first, third, fifth, etc., days were plotted. These curves were plotted for each city in turn. The results at St. Louis were so arranged that the result for the Illinois river was placed opposite the combined results of the Missouri and
187 Mississippi rivers so that they can be directly compared.

The variations between the Illinois, the Mississippi and the Missouri river, as indicated on this chart, show that the Illinois river has the effect of a city of 13,000 situated immediately above St. Louis, the Missouri river a city of 96,000, and the Mississippi river a city of 107,000, or a relation of 13, 96 and 107. In making this chart, Mr. Crane based the same upon the following populations:

Missouri river:	
Omaha, South Omaha and Council Bluffs	154,000
Plattsmouth	4,964
Nebraska City	7,380
St. Joseph	103,000
Atchison	15,700
Leavenworth	20,700
Kansas City	215,000
Independence	6,974
Lexington	4,190
Boonville	4,377
Jefferson City	9,664
St. Charles	7,982

	The Mississippi river:	
	Minneapolis and St. Paul, combined	365,783
	Red Wing	7,525
	Winona	19,714
	LaCrosse	28,895
	Dubuque	36,297
	Galena	5,005
	Clinton	22,698
	Davenport, Rock Island and Moline	71,995
	Muscatine	14,073
	Burlington	23,201
	Ft. Madison	9,278
	Keokuk	14,641
	Quincy	36,252
	Hannibal	12,780
188	Louisiana	5,131
	Alton	14,210
	The Illinois river:	
	Chicago	1,698,000
	Joliet	29,353
	Morris	4,273
	Ottawa	10,588
	LaSalle	10,446
	Peru	6,863
	Spring Valley	6,214
	Peoria	56,100
	Pekin	8,420
	Beardstown	4,827

It will be observed from the foregoing chart and statement that 18½ days was used as the time for the water to pass from

Chicago to St. Louis. If this time limit be decreased to ten days, which is more than the time limit as shown by the experiments conducted by Prof. Van Ornum, the result will be that the sewage from the city of Chicago, containing two millions of people, together with the sewage discharged from the cities discharging along the Illinois river, would result in sufficient typhoid dejecta passing from those cities to the city of St. Louis equal to the typhoid dejecta discharged into the river by a city having a population of 160,000 people, and according to the total per cent and the testimony of Mr. Hering and Mr. Crane, would result in the establishment of a city immediately above St. Louis having a population of 160,000 people. It might be well here to remark that as the velocity of the waters of the Illinois river increase according to the volume therein contained, that this imaginary city would rise and fall in increasing proportions with the increased velocity of water coming down from Chicago to St. Louis. This, in our judgment, is a very striking example of the effect of the Chicago sewage upon the waters of the Mississippi river at the intake, based upon the typhoid longevity of Hiram F. Mills, which is the one practically used by all sanitarians and scientists, showing conclusively and strikingly the very marked effect of the waters of the Illinois river upon the Mississippi river, and which demonstrates unquestionably
189 the fact that large quantities of typhoid fever germs pass from Chicago to St. Louis. (See Hering's testimony, Vol. 7, pp. 7000 to 7029.) (Crane's testimony, Vol. 7, pp. 7008 to 7018, inclusive.)

Mr. Alvord, one of the complainant's rebuttal witnesses, prepared a similar chart to that prepared by Mr. Crane, being a schematic representation of the reduction of typhoid bacterial pollution in Illinois rivers, using the same data as proposed by

Mr. Hering and Mr. Crane in their diagrams and chart. The chart prepared by Mr. Alvord is found at page 7782 of the record. This chart demonstrates clearly the proportionate numbers of bacteria that reach the city of St. Louis from Chicago through the Drainage Canal, the Illinois river and the Mississippi river, based upon the table prepared by Mr. Hiram F. Mills, which is generally relied upon by sanitarians in their investigations of water supplies. Mr. Alvord based the chart upon 20 deaths per 100,000 population, while Prof. Van Ornum's estimates as to the velocity of the river from Chicago to St. Louis were used instead of the velocity found by Prof. Randolph. The curve plotted upon the chart indicates the relative typhoid bacterial pollution, so far as the same can be predicated upon the population, by using the bacterial reduction found in the experiments of Hiram F. Mills and substantiated by Dr. Horrocks. This chart, together with the chart prepared by Mr. Hering, has reference to bacteria coming from patients who have died of the disease. It may also be considered as applying to patients on the Illinois river watershed sick of typhoid fever and who survived. Assuming active typhoid contamination to be proportioned to the population, and assuming diminution in the number of typhoid germs day by day to be as shown in the experiments of Mr. Hiram F. Mills, and basing the normal flow in the Illinois river from Chicago to St. Louis at about 15 days, the typhoid infection reaching the city of St. Louis from the population upon the Illinois watershed, calculated upon a death rate of 20 deaths per 100,000 population, would represent a city of 90,000 people, while on the basis of the flow as gauged by Prof. Van Ornum in his testimony, the infection arising at the

Chain of Rocks, at St. Louis, would be equivalent to the
190 population of a city of 400,000. This city would be situ-

ated immediately above the intake tower, with a typhoid death rate of 20 deaths per annum per 100,000 population.

With a maximum flood, such as occurs only once every seven years, it appears that the comparative pollution reaching the intake of the St. Louis waterworks would be equivalent to a population of a city of 960,000 with a typhoid fever death rate of 20 deaths per 100,000 living, this latter assumption being based upon the movement of the pollution vehicle from the Chicago river to the Chain of Rocks in eight days. (See Alvord's testimony, Vol. 8, pp. 7781-87, inc.)

It will also be noticed that based upon the typhoid death rate of 20 deaths per 100,000 population per annum, the death rate at Chicago for the year 1902 represents a population of 3,750,000, for 1903, 2,950,000, for 1900, 1,685,000, 1901, 2,505,000. The above figures, however, represent a greater population than actually exists in Chicago, but at the same time they represent the population of a city where the typhoid mortality rate is not more than 20 deaths per 100,000 population.

19.

ST. LOUIS WATER SUPPLY RENDERED UNFIT FOR DOMESTIC USE BY BEING POLLUTED WITH THE SEWAGE OF CHICAGO AND INFECTED WITH PATHOGENIC BACTERIA AND DISEASE PRODUCING ORGANISM FROM THE SEWERS OF CHICAGO.

The impurities increased very rapidly in the St. Louis water after the opening of the Drainage Canal. Throughout the entire time of this examination analytic results showed the water of the Mississippi river in an unsanitary condition. It was water that would be condemned by water specialists. The figures for nitrites and free ammonia being far beyond those allowed in the potable water.

(Prof. Keiser's testimony, printed record, Volume 2, page 1073.)

It will also be observed that the chemical observations of
191 the water of the Mississippi and Missouri rivers show these two waters to be of a stable character, while the water in the Illinois river exhibits a very unstable character. This stability of the upper Mississippi river and the Missouri river waters is made apparent from the fact that the analysis shows the larger portion of the polluted material to be of a vegetable character, while the contaminating constituents contained in the water of the Illinois river is shown to be one from nitrogenous animal matter.

(Prof. Keiser's testimony, printed record, Volume 2, page 1077.)

A general comparison of the result of the analysis of water collected at Grafton, Illinois river at Grafton, Mississippi river above Grafton, St. Louis Intake Tower, Missouri river at Fort Bellefountaine, in the period 1899-1900, respectively, it is noticed that a general increase takes place in nitrites and free ammonia in the waters of the St. Louis Intake in 1900 over conditions existing in 1899. The water discharged in the Mississippi river at Grafton is unquestionably more polluted in 1900 than in 1899. This increased pollution of the Illinois river necessarily results in an increased pollution in the Illinois river at Hartford and at the Intake. The result shows that the water entering the Intake in 1900 was more polluted than in 1899. This increased pollution, with no corresponding increase pollution in the Mississippi river above the mouth of the Illinois or the Missouri river above its mouth, must of necessity be attributed to the increased pollution of the Illinois river in 1900. The increased pollution of the Illinois river in 1900 is shown by the chemical analyses made by Dr. Teichmann following the opening of the Drainage Canal at Chicago, and thus we conclude that the opening of the Drainage Canal resulted in an increased pollution of the St. Louis water supply.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1245-1246-1247 and 1267.)

192 What is said with reference to the Illinois river during the period 1900, is also found to exist during the entire year of 1901.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1268-1269.)

During the period 1901, free ammonia was much lower in the Mississippi river above the mouth of the Illinois river than the water in the Illinois river above Grafton. Free ammonia at

Alton and Hartford and St. Louis Intake was much larger than in the Mississippi river above Hartford or the Missouri river at Fort Bellefontaine. The final results as to chlorine, nitrates and nitrites show that the contaminating products in the waters of the Mississippi river at the Intake are due to the unsanitary condition of the Illinois river rather than that of the upper Mississippi river and the Missouri.

(Prof. Teichmann's testimony, printed record, Volume 2, pages 1270-1276, inc.)

At page 1306, Volume 2, Professor Teichmann testified substantially thus:

"After having examined these waters chemically in the manner in which you described, and after having had considerable experience in water analysis, I am able to state that the outfalls of the sewers in Chicago passes into the Drainage Canal, from thence into the Des Plaines and Illinois rivers, the Mississippi river, and from thence into the Intake of the St. Louis water supply, and that the sewage of Chicago will this way enter into the St. Louis water supply and is distributed to the people of St. Louis. I am further able to state from my examination and experience that the water supply of the city of St. Louis since the opening of the Drainage Canal has become more polluted by reason of the opening of the Chicago Canal and the inflow of the sewage from the city of Chicago, than it was prior thereto."

In cross-examination, page 1445, Professor Teichmann said: "I consider it in a measure as very striking that with the increase of the pollution of our water supply, and with the increased pollution of the Des Plaines river from the Drain-
193 age Canal, and the Illinois river and the Mississippi river down to the Intake in the year 1908, there was a corres-

ponding increase in typhoid fever of 1300 per cent over the average of the five years preceding. In other words, that almost a typhoid fever epidemic followed the pollution of the water supply at the opening of the canal, as traced up the Mississippi river, then up the Illinois river and the Des Plaines river into the Chicago Drainage Canal, and that this high pollution of the Mississippi river, caused by the Illinois, produced an effect upon the typhoid condition in St. Louis never before experienced in that city during the month of March, and that the city never experienced such high pollution, such sewage polluted water as went into the Intake Tower, through the reservoir and distributed to the people of St. Louis, as in the month of March, 1900."

By comparing the analytical results of 1899, prior to the opening of the canal, with those of 1900, 1901 and 1902, after the opening of the canal, it will be found that the water became worse in its chemical character since the opening of the canal.

A very remarkable presentation of the effect of the sewage of Chicago upon the water of St. Louis is shown by the testimony of Professor Keiser, volume 2, pages 1697 to 1710, which is herewith presented verbatim, in order that its full effect may be readily observed:

"Q. Professor Keiser, I will ask you if you have made an examination, from data furnished you by the Board of Health of the city of St. Louis, of the condition of the water supply of St. Louis, and subsequent and prior to and after the opening of the Chicago Drainage Canal?

"A. Yes, sir.

"Q. Will you state briefly the result of your examination?

"Q. State where you got the data?

"A. I obtained the data from the Water Commissioner of St. Louis, Mr. Edward Flad, and from the office of the City

Chemist, Dr. Teichmann. I received it from Dr. Teichmann, also some data from my own laboratory, the Washington University chemical laboratory.

"Q. Now, you may state the result of your examination?

194 "A. In the first place, I have tabulated all the analyses that were made of the waters of St. Louis prior to the opening of the Chicago Drainage Canal, and I find that the records go back to the year 1894. In the first place, there are reported seventeen analyses of water from the distributing well. These analyses were made from May 2, 1893, to January 24th, 1894. They are reported in the Mayor's message—the Mayor of St. Louis, annual message for 1894, page 418, and here are these analyses taken out of the Mayor's message for 1894 (exhibiting sheets of paper). The average results as here printed for the condition of the water supplied to St. Louis are as follows:

Free ammonia—this is the average of the seventeen analyses—free ammonia .046.

Nitrites—that means parts per million of nitrogen—nitrites .003 parts per million.

Albuminoid ammonia 1.033 and nitrates .38 parts per million.

Then we have in the same report seventeen analyses of water from the settling basins made from April 14th, 1893, to January 24th, 1894, and they gave the following average results:

Free ammonia	.019
Nitrites	.002
Albuminoid ammonia	.411
Nitrates	.44

"Then a series of twenty-one analyses were made at intervals from December 15, 1892, to April 20th, 1894, in the chemical laboratory of Washington University. They gave the following

average results. These are the originals, the twenty-one analyses. Now the average at the bottom is as follows:

"Free ammonia	.048
Nitrites	.005
Albuminoid	.310
Nitrates	.38

"In addition to these results, twenty-six analyses were made by the city chemist of the intake water at intervals from September 9th, 1899, to January 22nd, 1900. The average values for these analyses are as follows:

195	Free ammonia	.063
	Nitrites	.002
	Albuminoid ammonia	.552
	Nitrates	.39

"Comparing these averages obtained in different years we see that there was but very slight change in the character of the water supplied to St. Louis. The free ammonia ranged between—

"Q. What year are you talking about?

"A. Supplied to St. Louis previous to the opening of the drainage canal.

"The free ammonia ranged between .019 and .063 parts per million. The nitrites varied from .002 to .005; the albuminoid ammonia, from .310 to 1.033, and the nitrates were practically constant. The maximum value for free ammonia before the water of the Drainage Canal reached St. Louis was .138 on January 21st, 1900, and for nitrites the maximum value was .01 on the same day.

"These analyses that are recorded prior to the opening of the canal show that the water was comparatively stable, and that it was not an unwholesome water compared with its present condition.

"Q. Now give the condition of the water after the opening of the canal?

"A. On January 17th, 1900, the Drainage Canal was opened. The water must have reached St. Louis about the beginning of February, 1900, and the effect of that opening on the St. Louis water is clearly seen in the results of the analyses made daily during the month of February—twenty-eight daily analyses of intake water made by the City Chemist gave the following values:

"Free ammonia	.217
Nitrites	.013
Albuminoid ammonia	.676
Nitrates	.6

"The impurities tend to increase during March, as is shown by the following value for thirty-one daily analyses in March, 1900:

	"Free ammonia	.348
196	Nitrites	.014
	Albuminoid ammonia	1.202
	Nitrates	.8

"The average results for April, 1900, were

Free ammonia	.186
Nitrites	.020
Albuminoid ammonia	1.036
Nitrates	.6

"A portion of this increase in free ammonia and nitrites noticed in February and March, 1900, may have been due to the fact that in the winter months impurities usually are found to run higher than in spring and summer, but the increase in the months of February and March, 1900, was very much greater than had been observed in any previous analyses, and further the water from this time on was found to have been perma-

nently changed. Subsequent analyses show that in the spring and summer months, following, the water did not return to its former condition, but had been permanently polluted; thus the monthly averages for April, May and June, and for each following month until June, 1901, are as follows: And I have here a table:

"Said table is in words and figures as follows:

	Free Am.	Nitrites.	Alb. Am.	Nitrates.	Chlorine.
April, 1900,	.186	.020	1.036	.6	9
May, 1900,	.094	.011	1.190	.5	10
June, 1900,	.070	.004	1.148	.3	11
July, 1900,	.127	.004	1.350	.3	10
Aug., 1900,	.101	.005	.810	.4	12
Sept., 1900,	.093	.004	.818	.7	15
Oct., 1900,	.118	.006	.898	.6	9
Nov., 1900,	.098	.007	.705	.6	10
Dec., 1900,	.105	.011	.289	.4	17
Jan., 1901,	.144	.009	.396	.8	19
Feb., 1901,	.121	.007	.296	.7	19
Mar., 1901,	.310	.013	1.455	1.3	11
197					
April, 1901,	.191	.016	1.034	1.1	6
May, 1901,	.088	.002	.506	.4	9
June, 1901,	.105	.002	1.161	.5	10

"A. (Continuing): The average results for this table are as follows:

Free ammonia	.150
Nitrites	.009
Albuminoid ammonia	.880
Nitrates	.6

"Comparing this now with the average result before the opening of the canal, namely,

Free ammonia	.063
Nitrites	.002
Albuminoid ammonia	.552 and
Nitrates	.39

We see that there has been a very decided increase in each of these forms of nitrogen, and that the chemical analyses show a permanent pollution of the water.

"According to generally accepted standards of potability a water having .150 parts of nitrogen as free ammonia, and .009 parts of nitrogen as nitrites, would be condemned as unsanitary.

"Q. Now give us the sanitary condition of the Missouri river water before and after the opening of the Drainage Canal.

"A. In looking over the statistics of the Health Department of the city of St. Louis, I found eleven analyses of water of the Missouri river taken at a point above the mouth of the stream are on record in the Health Department of the city of St. Louis.

"The average results of these analyses were:

Free ammonia	.080
Nitrites	.001
Albuminoid ammonia	.657
Nitrates	.4

And the average values of eight analyses made in the chemical laboratory of Washington University of Missouri river water taken at Fort Bellefontaine, Missouri, from January 23rd to January 31st, 1900, are as follows:

	Free ammonia	.134
	Nitrites	.008
198	Albuminoid ammonia	.342
	Nitrates	.39

"The average of all these recorded analyses of Missouri river water prior to February 1, 1900, are as follows:

Free ammonia	.107
Nitrites	.0045
Albuminoid ammonia	.499
Nitrates	.39

"After February 1, 1900, daily analyses of Missouri river water were made by the City Chemist until October 10, 1900, and also during the period October 1, 1901, to November 30, 1901:

Free ammonia	.142
Nitrites	.007
Albuminoid ammonia	1.203
Nitrates	.5

"And for the second period the averages are:

Free ammonia	.069
Nitrites	.003
Albuminoid ammonia	.631
Nitrates	.55

"Now the averages of both of these series are as follows:

Free ammonia	.105
Nitrites	.005
Albuminoid ammonia	.917
Nitrates	.5

"Comparing these averages now with the averages of analyses before February 1, 1900, namely:

Free ammonia	.107
Nitrites	.0045
Albuminoid ammonia	.499
Nitrates	.39

"We see that there is but a slight difference in the average condition of the Missouri during these two periods. In other

words, the Missouri river during the period of September 2, 1899, to November, 1901, has undergone no permanent change in the sanitary character. The same fact is shown by comparing the average results obtained by the city chemist on September 2 to December 4, 1899, with the average results obtained by him in October and November, 1901. Those analyses in the form of an average give:

Free ammonia	.080
Nitrites	.001
Albuminoid	.657
Nitrates	.4

"In the later period, which was two years later, but at the same time of the year, we find

Free ammonia	.069
Nitrites	.003
Albuminoid ammonia	.631
Nitrates	.55

"We see from these that while St. Louis water had undergone a marked deterioration, the Missouri river water had remained unchanged. It is true that in the winter months the impurities in this river are higher than in the summer. This is true of all streams, but we see that in the fall of 1901 the water had again returned to its former condition. The results show, then, that the increase of impurities in the St. Louis water did not come from the Missouri river.

"Q. Those are conclusions arrived at based upon the data which you have given, are they not?

"A. They are.

"Q. Now give us the sanitary condition of the Mississippi river before and after the opening of the drainage canal.

"A. There are recorded in the Health Department of the city of St. Louis, analyses made by the City Chemist, seventeen

analyses of the Mississippi river collected at Hartford, Illinois, a point about one mile above the mouth of the Missouri river. These samples were collected at intervals between August 3, 1899, and December 4, 1899. The average results of these analyses are as follows:

Free ammonia	.107
Nitrites	.004
Albuminoid ammonia	.622
Nitrates	.5

200 "These were all made before the opening of the drainage canal. After the opening daily analyses were made from January 23, 1900, to October 10, 1900, upon samples taken at Hartford. The average values for these analyses are as follows:

Free ammonia	.275
Nitrites	.018
Albuminoid ammonia	.613
Nitrates	.7

"Daily analyses were also made from October 1 to November 30, 1901, and the averages obtained were:

Free ammonia	.062
Nitrites	.011
Albuminoid ammonia	.368
Nitrates	.54

"Averaging both series that were made subsequent to the opening of the drainage canal we get:

Free ammonia	.236
Nitrites	.017
Albuminoid ammonia	.568
Nitrates	.67

"Comparing these results with the average condition of the Mississippi river at the same point before the opening of the canal, namely:

Free ammonia	.107
Nitrites	.004
Albuminoid ammonia	.622
Nitrates	.5

We see that there has been a permanent increase of the pollution of the water. The water of the Mississippi, like that of the St. Louis intake, has been very materially inferior in sanitary quality since February, 1900, and further, these analyses show that since the St. Louis water is a mixture of the water of the Missouri and the Mississippi the increased impurities of the St. Louis water must have come from the Mississippi river, and not from the Missouri river.

"Q. Now give the condition of the Mississippi river above the mouth of the Illinois river.

201 "A. It having been shown by the previous analyses that the Mississippi river is a carrier of the impurities to the St. Louis intake, it is now of importance to determine how these impurities find their way into the Mississippi. The question arises: Do these impurities come down the main stream of the river or from the Illinois river? Eighteen samples of water were taken from the Mississippi river at a point above the mouth of the Illinois river. These samples were collected at intervals between September 6, 1899, and January 17, 1900. The average values of the analyses made by the City Chemist are as follows:

Free ammonia	.069
Nitrites	.002
Albuminoid ammonia	.503
Nitrates	.3
Chlorine	6.0

"Daily analyses of the water from this point were also made from January 23, 1900, to October 10, 1900. The averages obtained are as follows:

Free ammonia	.138
Nitrites	.008
Albuminoid ammonia	.587
Nitrates	.46
Chlorines	5.0

"Daily analyses were again made from October 1 to November 30, 1901, and the averages obtained were:

Free ammonia	.057
Nitrites	.001
Albuminoid ammonia	.348
Nitrates	.1
Chlorines	4.3

"Comparing these with the results as given, we see that the Mississippi river above the mouth of the Illinois, while higher in impurities in the winter months, returned in the fall of 1901 to a condition very similar to that which it was in 1899. The amounts of free ammonia and nitrites are relatively low in this stream and it is very similar in sanitary character to the Missouri river above its mouth. Plainly then, the upper Mis-
202 sissippi is not the source of the impurities that pollute St. Louis water.

"Q. Now, professor, give the results of the analyses of the Illinois river made three miles above Grafton.

"A. Nineteeen samples of the water of the Illinois river from a point three miles above Grafton were collected and analyzed by the City Chemist at intervals between September 6, 1899, and January 17, 1900. That was before the opening of the canal. The average values found are as follows:

Free ammonia	.215

Nitrites	.012
Albuminoid ammonia	.553
Nitrates	.8
Chlorine	25.0

"These results show that at this time the water was badly polluted and not fit for drinking according to accepted standards. From January 23rd to October 10, 1900, daily analyses were made of water from the same point, and again in October and November, 1901. The averages for the first series are as follows:

Free ammonia	.272
Nitrites	.032
Albuminoid ammonia	.509
Nitrates	.96
Chlorine	13.0

"For the second series:

Free ammonia	.110
Nitrites	.043
Albuminoid ammonia	.373
Nitrates	1.71
Chlorine	21.6

"The average values for both series of analyses are as follows:

Free ammonia	.239
Nitrites	.034
Albuminoid ammonia	.482
Nitrates	1.11
Chlorine	14.7

203 "We see from these that for the ten months since the opening of the drainage canal there was an increase in free ammonia of nearly 27 per cent and of nitrites of 167 per cent. We can only conclude from these figures that after the canal was

opened there was a much larger quantity of sewage undergoing putrefactive changes than before in 1901, although the proportion of free ammonia had fallen somewhat, the nitrites had gone up to .043 parts per million, an increase of 258 per cent over what they were before the opening of the drainage canal. The Illinois river is thus shown to be the stream which, with its high free ammonia and nitrites, contaminates the Mississippi, and the Illinois river at its mouth is found to be in a much more polluted condition since January 23, 1900, than it was prior to that time. It is, therefore, the Illinois river that has caused the permanent increase in the impurities of the St. Louis water. The analyses have shown that both the Missouri river and the Mississippi river above the Illinois have undergone no permanent change, but the Illinois river has been rendered more impure as a result of the opening of the drainage canal.

"Q. Now can you give the condition of the Illinois river at the points above Peoria?

"A. There were no analyses of the water of the Illinois river at points above Grafton made by the City Chemist before the opening of the canal, but from January 23, 1900, to October 10th the same year, daily samples were taken at a point three miles above Peoria, and occasional samples at Joliet and at Lockport. Samples were also taken from the Illinois and Michigan Canal and from Lake Michigan. These analyses show that as we ascend the river from Grafton to Chicago, the water becomes steadily more and more impure. This fact is clearly shown by the average values obtained from the Illinois: Thus, the average values from samples taken three miles above Grafton are as follows:

Free ammonia	.239
Nitrites	.034
Albuminoid ammonia	.482

Nitrates	1.11
Chlorine	14.7

204 "The average values for samples taken three miles above Peoria are as follows:

Free ammonia	.568
Nitrites	.095
Albuminoid ammonia	.284
Nitrates	1.48
Chlorine	19.4

"And the average values from samples taken at Joliet in 1901 are as follows:

Free ammonia	2.732
Nitrites	.057
Albuminoid ammonia	.425
Nitrates	.22
Chlorine	23.9

"And the averages of samples taken from the Illinois and Michigan Canal are as follows:

Free ammonia	13.250
Nitrites	.009
Nitrates	None
Chlorine	150.0

"The averages from the Drainage Canal, Lockport, Bear Trap Dam, are as follows:

Free ammonia	1.585
Nitrites	.026
Nitrates	.15
Chlorine	15.0

"Now for the sake of comparison, the averages of the water from Lake Michigan are as follows:

Free ammonia	.043
Nitrites	.005

Nitrates	.15
Chlorine	6.0

"Q. Now what conclusions do those results show or lead you to?

"A. We see that the entire Illinois river is in a highly polluted condition. The figures obtained at Joliet and those for the Illinois and Michigan and Drainage Canals are such as would have been obtained from sewage in its early stages of de-
205 composition. Lake Michigan has .043 parts of free ammonia and .005 parts of nitrites. Now by the admixture with the sewage in the Chicago river, we find that when it reaches the drainage canal the free ammonia has increased to 1.585 and nitrites to .026 parts per million. The Illinois and Michigan Canal is still more highly charged with sewage and gives 13.250 parts of free ammonia. These two canals carry sewage into the Illinois river by dilution with the water of the river, we find free ammonia .468 at a point three miles above Peoria. The nitrites, however, at this point are higher, namely, .095. Going down then to Grafton we find that the free ammonia has fallen to .239, and the nitrites to .034, but this is still far from being in a condition fit for drinking. We see that the oxidation and self-purification processes become very slow as the concentration of the sewage is diminished, and for the same reason we find these impurities in the water of the Mississippi and in the water of the St. Louis waterworks."

(Prof. Keiser's testimony, printed record, Volume, 2, pages 1697-1710.)

Again, Prof. Keiser testified as follows:

"Q. Professor, I want to ask you this question. You say that you did not consider the chlorine as an element in determining the potability of the water of the Missouri river because you

attributed that chlorine to mineral origin and not to vegetable or animal?

"A. Yes, sir.

"Q. Now, isn't it a fact, independent of any knowledge as to the origin of the chlorine, that the water contains high chlorine and low ammonias and low nitrites or an absence of nitrates, that is shows that the chlorines are not attributable to animal or vegetable origin, but must be attributed to mineral origin?

"A. Yes, sir.

"Q. And you found those conditions present in Missouri waters?

"A. I did.

"Q. And that did not apply to any of the other streams?

"A. No, sir.

206 "Q. So that if you knew nothing about the chlorine in the Missouri, coming from the Kaw river or from any other mineral source, you would still come to the conclusion that they were attributable only to mineral salt source?

"A. Yes, if the ammonias are low. If the ammonias and nitrites are low, and if we find all forms of nitrogen low, low nitrites and low nitrates, then find high chlorine, the water is no longer contaminated and it may show that the water was at one time contaminated, but the forms of nitrogen have been removed, and while the mineral matters may be high, the chlorine might be high, it would in all probability come from salt layers or salt springs.

"Q. And if the chlorine could be attributable to animal or vegetable origin, then you would say as a chemist that the nitrites and the free ammonias must be correspondingly high.

"A. Yes, sir.

"Q. And if they are not, it shows that they did not come from sewage pollution?

"A. Yes, sir.

"Q. And that is the condition of the Missouri river?

"A. Yes, sir."

(Prof. Keiser's testimony, printed record, Volume 2, pages 1724-1725.)

In this connection Dr. Ravold testified as follows:

"Q. Now, Doctor, I will get you to state whether or not you considered this water potable and safe for drinking purposes that comes from the Intake tower of the St. Louis Waterworks now without filteration and without boiling?

"A. I do not.

"Q. Now, doctor, in the cross-examination of General Hamlin yesterday you persisted in using the term disappearance, asking the question as to whether or not the increase volume of the water by the opening of the Chicago Drainage Canal and pouring the Lake Michigan water into the same thereby caused dilution, would tend to increase the dilution in the Des Plaines river and consequently the disappearance of bacteria of any kind that might be in the water of the Des
207 Plaines and Illinois rivers, and I want to ask you to explain what you meant by the term disappearance as used in reply to his question?

"A. I meant by this that the bacteria were not killed, they were not destroyed by the dilution, but they were moved farther apart. I said at the time that if we had a gallon of water with 100 bacteria in it and added 99 gallons to it, we would have the first 100 to one gallon and by adding 99 to it, it would be diluted one to 100, and there would then be one bacilli to one gallon of water, the bacilli not having disappeared, but are removed farther apart.

"Q. State whether or not dilution would in any way destroy pathogenic germs.

"A. It does not destroy them.

"Q. I will ask you this question: Do you consider, as a bacteriologist, from your knowledge of water supply of St. Louis prior to the opening of the Chicago Drainage Canal, and your knowledge of said supply since the time of the opening thereof, that the water supply at the Intake tower of this city has been rendered less wholesome and safe for domestic and primary use than before the opening of the canal, and if so, is it occasioned by the waters from the canal?

"A. I think it is less wholesome, and I can prove it chemically and bacteriologically. Do you wish the reason?

"Q. You can state them.

"A. Formerly the sewage of Chicago, before the opening of the Chicago Drainage Canal, was discharged into what was practically a large tank and that was the Chicago river, a river which discharged itself when the lake was lower than the water in the river or when freshets occurred which swept the water of the river out into the lake, which occurred semi-occasionally; but as a rule the water was stagnant in the river containing the sewage. That stagnant sewage putrified, was broken up by aerobic and finally by anaerobic action until the whole river was a fetid, stinking mass. It remained in that river for quite a length of time. In order to purify the river and to create a current in it, pumps were put in at Bridgeport and the sewage pumped into the Illinois and Michigan Canal in certain
208 quantities, a certain quantity was lifted from the South Fork into the Illinois and Michigan Canal. This sewage practically received the treatment afforded by a septic tank and all the pathogenic bacteria were practically dead in it before they reached Bridgeport, because the pumps at Bridgeport made

no perceptible current in the Chicago river towards the pumps. I tried this experiment several times myself by throwing a board into the river and watching it for several days, and it never moved more than a block either way in 24 hours. So the current towards the pumps was very small according to my actual experience. So, in my opinion, the putrifying material in the river would destroy any pathogenic bacteria, such as typhoid, left in it for any length of time, or for a short time. Now, however, this condition does not obtain, and the typhoid bacteria and other pathogenic bacteria discharged into the stream are hurried through it. In the Chicago river now the rate of flow is something like three miles an hour, sometimes more than that. In August or September of 1901, Mr. Randolph and I watched a boat trying to get by a bridge, and the boat had not enough power to force itself up the river towards the lake in a current then running fully three miles an hour. That was at five o'clock in the evening when the gates were lowered at Lockport and the full quantity, 300,000 cubic feet, was being discharged. The sewage is now carried from the Chicago river into the Drainage Canal, and from there on to Lockport and then into the Des Plaines and Illinois rivers, so that the chances of pathogenic bacteria vitalized and strong as they come from the bowels of an individual, being carried down to St. Louis' water supply, is infinitely greater now than when the pumps were at work.

"Q. I will get you to state if you are acquainted with the condition of the Illinois and Michigan Canal, as to whether there is any flow or current in this canal?

"A. There is a current in that canal.

"Q. Is it rapid or slow?

"A. Slow, slow at all the periods when I saw it. There may be periods when it is rapid, but I never saw one of those periods.

209 "Q. Now, in answer to a question of Gen. Hamlin yesterday, you stated that it might be that typhoid bacilli, traveling from the sewage of Chicago by the canal, the Des Plaines, Illinois and Mississippi rivers and coming into the Intake here, of the waterworks of St. Louis, would be, perhaps, less virulent in form than if they traveled a distance of 10 or 15 miles and then came into the Intake, I will get you to state whether or not, if they were still alive, that would prevent them from causing typhoid fever?

"A. No, sir.

"Q. In taking them into the bowels?

"A. No, sir. To an equally susceptible individual the chances of a nearby bacillus having greater vitality are greater, so that the disease produced in an equally susceptible individual, the disease produced by a nearby typhoid bacillus would be of more severe type than that produced by bacilli carried some distance.

"Q. But each would produce the typhoid disease?

"A. Yes, sir.

"Q. In an equally susceptible individual?

"A. Yes, sir.

"Q. But one would be of a milder form?

"A. But one would be of milder form.

"Q. Now, I will get you to state if there is any difference medically or bacteriologically from your knowledge as to the virulency of a typhoid disease conveyed in a germ of bacteria that comes from a man sick from a mild form of tphoid and one sick with a virulent disease of typhoid?

"A. No, in passing through the individual their virulency is greatly increased. Bacteriologically that is a thing which is done every day. In order to increase the virulency of a micro-

organism it is put into the blood of a susceptible animal and its virulency can be greatly increased in that way.

"Q. That would be the effect on a person taking into the system a typhoid bacillus from one sick with mild form of that disease as to whether he would have a mild or severe form?

"A. He would have a severe form if bacteria were to be put into a susceptible individual; coming from a mild case
210 or severe case it would not matter very much, the virulency would be heightened by the transit through the individual.

"Q. Provided they were equally susceptible in both cases?

"A. Yes, sir.

"Q. General Hamlin asked you a question yesterday if it was not fact that the recorded cases showed 50 miles or less as the distance that bacilli traveled through water and produce disease. I will ask you to show why the records show that to be more or less the fact?

"A. Because of the difficulty of tracing the micro-organism under the complex conditions of modern life. If it were an open river in which the typhoid bacillus were under consideration, the possibility of the river being affected from cases of its banks or other extraneous sources must be weighed, so that to trace an epidemic more than 50 miles is an extremely difficult thing to do, except under such conditions as that of the St. Clair Lake, Detroit epidemic. If the river were covered with a tunnel or running through a tunnel such as the Croton Aqueduct, for a number of miles, then we could say absolutely—for if a typhoid epidemic were to occur in New York, we would feel perfectly confident that no extraneous case of sewage discharge came into the tunnel from any other source than where the aqueduct opened on the watershed. In the Detroit case we had a remarkable instance. Here we had a bed of sewage in a river which had laid there for years and it was suddenly disturbed by dredging

and was carried across a lake. It was practically as if in a tunnel, because the sides of the lake were so far away that the one or more cases which might have discharged feces on the periphery of the lake could have no effect. If the material had been carried straight away in a tunnel it could not have been carried more directly to Detroit than it was. That this was the cause of the outbreak of typhoid fever in Detroit Professor Williams has declared on and so reported."

(Ravold's testimony, Vol. 1, pp. 837-949-950-951-952-953.)

The contents of the Chicago Drainage Canal, after entering the Des Plaines river above Bear Trap Dam at Lockport, flow along the Des Plaines river, and the two currents flow
211 into the Illinois river. From thence they flow to Grafton, a distance of 291 miles from Lockport. The time required for this flow may be safely estimated at from ten to twenty days, the range, of course, depending upon the velocity of the flow of water in the river. There are portions of the stream, namely the upper portion, which flow more rapidly than the lower portions, and some water presumably reaches Grafton quicker than indicated by the average above mentioned. The dilution of the Chicago sewage, as it flows from Lockport to Grafton, by the waters of the Illinois river and tributaries, is a very variable proposition. At times the dilution of the contents of the Chicago Drainage Canal by the flow of the Illinois river and its tributaries is very considerable. At other times the flow of the Chicago Drainage Canal exceeds the flow of the Illinois river, this being particularly true in its upper reaches; consequently there results at times a dilution of the Chicago sewage by the waters of the Illinois river, and other times a dilution of the Illinois river by the contents of the Chicago Drainage Canal.

Dilution at best does not destroy disease germs or infectious matter. Its effect is to minimize the danger to those who may drink of the water so infected. One effect of the dilution existing in the Illinois river at low stages is to bring to Grafton more quickly than would otherwise be the case injurious matter entering the Illinois at points along the route of its flow, and also entering from Chicago and cities and towns located upon its tributaries. Nor can it be said that the locks and dams found along the course of the Illinois river are sufficient under any circumstances to arrest the progress of pathogenic bacteria down stream. While it is true that in a great many places during certain times of the year deposits of sediment may take place for a considerable time, and pathogenic bacteria suspended in the water may be carried downward and lodged upon the bed of the river, but this does not mean their permanent elimination and removal from the water; the reason is that as they reach the bottom and lie on the bed of the stream they are disturbed from time to time, caused by moderate rains or by the passage of boats, the action of the winds or the like. The resulting disturbances cause the bacteria to leave the bed of
212 the stream in which they may rest for some time, bringing about their return into the flowing water. In this way the germs of disease pass from the Chicago Drainage Canal at Lockport to the mouth of the Illinois river at Grafton, there being no question but what the typhoid fever germs do not disappear from the river entirely, and while some of them may submit to the processes of sedimentation in the flowing stream and become deposited in the bed, yet they are able to live there for weeks and months, so that such conditions may arise as will render the Illinois river at Grafton richer in typhoid fever germs derived from the Sanitary District of Chicago coming through the Drainage Canal than is that portion of the water

drawn from the Drainage Canal as it flows over Bear Trap Dam. So that in view of all the facts and conditions as found today, the sewage from the Sanitary District of Chicago pollutes and infects the water of the Mississippi river along the shore, and especially at the Chain of Rocks Intake Tower of the St. Louis Waterworks to such an extent as to render the Mississippi river water less safe for drinking purposes than it was prior to the opening of the canal on January 17, 1900. (Fuller's testimony, Vol. 3, pp. 2617 to 2621, inclusive; Fuller's cross-examination, Vol. 3, p. 2640-1; Hazen's testimony, Vol. 3, pp. 2799, 2801-2. Hazen's cross-examination, Vol. 3, page 2810.)

After making almost innumerable chemical examinations of the water of the respective rivers and studying the topography of the country and all of the physical surroundings appertaining to the question of infected water, and having made examinations of the water supply of the city of St. Louis prior to and since the opening of the Chicago Drainage Canal, Prof. Teichmann expressed it as his opinion that the water supply of the city of St. Louis is more polluted now by reason of the opening of the Chicago Drainage Canal and in the flow of the sewage from the city of Chicago than it was prior thereto. (Teichmann's evidence, Vol. 2, page 1307.)

Prof. Sedgwick, in his testimony, stated in this connection, as follows:

213 "In my opinion as an expert on water supplies for cities and towns, the water of the Mississippi river west of the center of the main channel below the mouth of the Illinois river down to the intake tower of the St. Louis Water Works at the Chain of Rocks is decidedly less valuable for drinking purposes, and more likely to carry water borne diseases, such as typhoid fever and cholera, now than it was before the sewage from the

Sanitary District of Chicago was run into the drainage canal and through it into the Illinois river. (Vol. 3, page 2194.)"

Prof. Sedgwick further says that the addition of such a volume of liquid as passes through the drainage canal must materially quicken the flow of the Illinois river, and must therefore hinder the effect of sedimentation by shortening the time required for infectious germs to pass through the river, and by interfering with their detention, and aggravating the danger of their arrival at the mouth of the river. I should like to say here that the time allowed in all these matters is very important, so that any quickening of the flow is a grave consideration. It is not so much the distance as the time, that is the basis of self-purification of streams.

When this is taken into consideration with the further statement made by Prof. Sedgwick, borne out by the evidence in the case, that at times the water passing the drainage canal represents five-sixths of the water flowing down the Illinois river, the conclusions arrived at by Prof. Sedgwick cannot be controverted. In addition to the foregoing, the effect of the added volume of water and increased flow of the river would shorten the time for carrying the sewage from Joliet, Peoria and other towns on the Illinois river to the Mississippi at Grafton, and at the Chain of Rocks. (Sedgwick's testimony, Vol. 3, page 2196.)

The increase made in the speed of the current in the Illinois river by the addition of the water from the drainage canal has the effect of increasing typhoid and liability to typhoid and other water borne diseases on the part of the inhabitants of the State of Missouri using the water of the Mississippi for drinking purposes below the mouth of the Illinois river. (Sedgwick's testimony, Vol. 3, page 2196.)

214 And speaking generally, such conditions as have existed since the opening of the drainage canal and the discharge

of sewage from Chicago renders the water of the Mississippi river at St. Louis unfit for drinking purposes and domestic use. (Sedgwick's evidence, Vol. 3, pages 2196-7.)

The water of the Illinois river, since the opening of the drinage canal, as it enters the Mississippi river, is one which should not be used for drinking purposes, and the fact that the pollution of the Illinois river is contributed to largely by the Chicago Sanitary District and from the large amount of typhoid fever in said district, the effect of the time interval, dilution and sedimentation occurring between Chicago and Grafton would not, emphatically not, be sufficient—be such as to render the water as it enters the Mississippi free at all times from producing water borne diseases to those who drink it. This for the reason that such processes of self-purification, including sedimentation and dilution, as would take place in the Illinois river, and above to Chicago would be inadequate to insure at all times and seasons a complete removal of infectious material. (Sedgwick's testimony, Vol. 3, pages 2199 and 2200.)

Prof. Sedgwick made a careful study of the typhoid fever statistics of the city of St. Louis with the general result that during the period of fifteen years prior to January 1st, 1900, the typhoid fever death rate in St. Louis had not in general been above that of some cities considered of good repute. During the period following the removal of the intake from Bissell's Point to the Chain of Rocks, the typhoid death rate of St. Louis was remarkably good, much lower than it had been and lower for example than the death rate of the city of Boston for the same period. Beginning with the first of January, 1900, there has been a marked annual increase in the typhoid death rate in St. Louis, so that it has during that period not only been

higher than during the previous period of five years, but has been higher than at any time in its previous history since 1885, and very much higher than the death rate of the city of Boston, with which previously it compared very favorably.

215 The increase since January, 1900, in the annual mortality from typhoid fever as compared with the preceding five years, has been 77 per cent. It might be well to state here that the water supply of Boston is considered a fairly good supply and ranks amongst the water supplies of the country as a good water supply, thus showing clearly, when taking into consideration the fact that there was no increase in typhoid in the principal towns and cities in Missouri on the Mississippi and Illinois rivers, exclusive of Chicago, that the opening of the Drainage Canal has caused the death rate to change from an annual decrease of 26 per cent to an increase of 77 per cent, comparing the conditions for the years immediately before the opening of the canal with those immediately after the opening of the canal. (Sedgwick's testimony, Vol. 3, 2202-2203.)

Since the opening of the Chicago Drainage Canal the water in the Illinois river has become much more infected by disease producing bacteria than prior thereto, and has been rendered less safe, and consequently has produced an unsanitary effect upon the waters of the Mississippi river below Grafton and at St. Louis. (Sedgwick's testimony, Vol. 3, pp. 2222-3-4-5 and 2253. See also Whipple's testimony, Vol. 3, pp. 2208, 2137, 2149, 2150, 2152, 2155.)

In this connection Mr. Gardner Williams stated as follows:

"I should say that the evidence of the typhoid fever statistics of the city of St. Louis for the period mentioned from 1895 to 1899 indicate that the water supply of St. Louis is not ideal, nevertheless it would compare favorably with that of a very

large number of American cities, and generally speaking it would entitle the St. Louis water supply to rate with about the second rate of water supplies as water supply experts usually consider them, and considering the evidence of typhoid statistics of the city of St. Louis since the beginning of 1900 it appears that up to near the end of January the water supply of St. Louis during the year 1900 must have been about as good as formerly, but that about that time there appears to be considerable infection, which has continued to increase from
216 time to time since, with the result that typhoid statistics show the infection during the years 1901 and 1902 to have been nearly twice as great as existed on the average from 1895 to 1899, inclusive, and that the rank of the water supply of the city of St. Louis has materially dropped, judged by the standard of water supplies.

"I have examined the record of typhoid fever in cities on the Mississippi, Illinois and Missouri rivers outside of the sanitary district of the city of Chicago, and I am unable to find anything in those statistics which would account for the large increase in typhoid fever in St. Louis since the 17th day of January, 1900. Basing my opinion on the facts brought out by our extended examination of the conditions which seem to bear on the questions involved, it is my judgment that the discharge of sewage from the sanitary district of Chicago into the Mississippi by means of the Chicago Drainage Canal, the Des Plaines river and Illinois is attributable to the major part of the increase of typhoid fever revealed by the typhoid fever statistics in the city of St. Louis since the beginning of 1900, as compared with from 1895 to 1899, inclusive." (Williams' testimony, Vol. 3, pp. 2462, 2463 and 2473.)

In reference to the question as to whether typhoid bacilli passed from Chicago to St. Louis, Mr. Whipple stated the following:

"From what I know about the life of typhoid fever bacillus in the water, and from my knowledge of the conditions which exist between the Chicago Drainage Canal and the intake of the water works at St. Louis at the Chain of Rocks, it is my opinion that typhoid fever germs existing in the sewage of Chicago will survive the passage down the Chicago Drainage Canal to the intake tower of the St. Louis Water Works at the Chain of Rocks under existing conditions. About one month ago I made a personal inspection of the Chicago river, and Chicago Drainage Canal, and Desplaines river as far as Joliet, and saw the point where the Chicago river naturally drains into Lake Michigan, saw the north branch of the Chicago river, the south branch of the Chicago river and the south fork of the south branch,
217 and what I believe is called the west fork of the south branch of the Chicago river, and saw the point where the Chicago Drainage Canal begins and its terminus at Lockport. I saw the Bear Trap Dam at that point and saw the Illinois and Michigan canal at that point. I noticed the place where it discharged into the DesPlaines river and saw the DesPlaines river at Joliet, and the dam at that place. It is my belief that, assuming the sewage and lake water passing from the Chicago river to the drainage canal reaches the Mississippi river at the Chain of Rocks in ten and a half days, typhoid fever germs coming from the sewers of Chicago will survive the passage through the Chicago Drainage Canal, Des Plaines river and Illinois river to St. Louis. I believe there are cases on record from my general knowledge of typhoid fever epidemics where epidemics have occurred which showed that they were caused by typhoid fever germs which had remained in water at least ten and a half days

prior to the entrance of the water into the service pipes in the community where the epidemic prevailed. (Whipple's testimony, Vol. 2, pages 1996 to 1999, inc.)

"From my knowledge of the existing conditions of the Chicago Drainage Canal, and of the several water courses between the canal and the intake tower of the St. Louis water works at the Chain of Rocks, there exists no work of artificial construction which insures the prevention of typhoid fever germs which may enter the Chicago Drainage Canal from reaching the intake of the St. Louis water works at the Chain of Rocks." (Whipple's testimony, Vol. 2, page 2002.)

Prof. Sedgwick, in Vol. 3, page 2314, in this connection, says:

"I am ready to assert my conviction, my positive conviction, that typhoid bacilli may and do live to make a journey from Chicago to St. Louis. Based on the whole chain of evidence which I have in my posssion regarding the sanitary history of Chicago, the character of water used to dilute the sewage of the city of Chicago, the character of the Illinois river, especially being subject to floods, the character of the Mississippi river into
which the Illinois river enters, and with which the Illinois
218 freely mixes, is that such germs may be carried alive and
virulent from the people of Chicago to the intake tower of the St. Louis water works, and further upon the vital statistics of St. Louis, having studied and compared them with the vital statistics of other communities."

Under existing circumstances and conditions from Lockport to Grafton, whether these conditions be taken separately or collectively, they are not suffiicent to prevent the polluting and infectious material from coming from the Sanitary District of Chicago down the Illinois river and entering the Mississippi at

Grafton, and the distance from Grafton to St. Louis of about 28 miles, and the time required for the water to flow from Grafton to St. Louis but one day, the waters of the Illinois river will become thoroughly mixed with the waters of the Mississippi by the time the Chain of Rocks is reached. (Fuller's testimony, Vol. 3, page 2621.)

Considering the greater concentration of the polluted matter contained in the Chicago river prior to the opening of the Drainage Canal than there is now in the main channel of the Drainage Canal, conditions are less favorable in the Chicago river since the opening of the canal than they were prior thereto. This is based upon the proposition that the slower the flow the less dilution and the more organic matter the more saprophytes, consequently the sooner the death of pathogenic bacteria. (See Zeit's testimony, Vol. 5, pp. 4510-11-52-53-54.)

The water of Lake Michigan, according to the analyses of Prof. Palmer and others, contains much less total organic nitrogen than is found in the waters of the Illinois river at Kampsville or at Grafton. It is a known fact that the waters of Lake Michigan, when consumed by the people of Chicago, have produced extraordinary results in typhoid fever. Considering that the flow of the stream from Chicago to Kampsville and Grafton is within the life limit of the typhoid germ, there is nothing in the science of bacteriology or chemistry as applied to streams examined which disputes the idea that typhoid bacilli will not pass from Chicago down the Illinois river to Kampsville, Grafton and St. Louis. When we take into consideration the fact
219 that there is more nitrogenous substance contained in the waters of the Illinois river than in Lake Michigan, it is difficult to avoid the conclusion that a great portion of the increase of typhoid fever in St. Louis is due to the Chicago sewage. In this connection Prof. Palmer stated:

"Whether the organic nitrogen contained in the water of Lake Michigan analyzed by me did or did not contain the micro-organisms which produce typhoid fever, I do not know, but assuming it to have been present therein, it is my opinion that there is nothing in my sanitary chemical analysis of the waters of the Illinois river at Kampsville which has determined whether or not a bacillus of typhoid fever was contained in that water. Now, assuming that there was the same relation between the numbers or amounts of micro-organisms in the waters of Lake Michigan and the Illinois river at Kampsville, then it is my opinion that the relation the numbers of said micro-organisms would have to each other would be similar to the proportions of the total nitrogenous organic matter in each of these two waters."

The average proportion of total organic nitrogen contained in the waters of Lake Michigan analyzed and testified to by Prof. Palmer for the year 1897 was .268 parts per million; for the year 1898 .202 parts per million; for the year 1899 .188 parts per million, and for the year 1900 .186 parts per million; the average for the years named being .211 parts per million. The average proportion of total organic nitrogen contained in the waters of the Illinois river at Kampsville in 1897 was 1.204; for the year 1898 1.018; for the year 1899 1.129; the average for the three years being 1.157. The average total organic nitrogen contained in the waters of the Illinois river at Kampsville during 1900 was .904, and 1901 was .999; the average for the two years was .951.

The relation the proportion of total organic nitrogen found in the waters of Lake Michigan for the four years, 1897 to 1901, inclusive, bears to the proportion found in the waters of the Illinois at Kampsville for the period 1897 to 1899, inclusive, is as one to five; in other words, one for Lake Michigan and five for the waters of the Illinois at Kampsville.

220 The proportions of organic nitrogen found by Prof. Palmer in the waters of Lake Michigan for the year 1900 and those found in the waters of the Illinois river at Kampsville for the same year were one for the waters of Lake Michigan and 4.86 for the waters at Kampsville.

Assuming that in the year 1899 there were a large number of cases of typhoid fever in Chicago, and that in the year 1900 there were a like number of cases of typhoid fever in that city, and assuming that in the year 1899 the discharges of the dejecta of those patients in Chicago reached the intake crib and were present in the water analyzed; and assuming that for the year 1900 the typhoid dejecta from the patients in the city of Chicago were discharged into the sewers of the city and thence into the Chicago river, the drainage canal, and through the drainage canal discharged into the Illinois river, there is nothing in the science of chemistry or in the chemical analyses which have been made of the waters of the Illinois river at Kampsville which discloses that these typhoid fever organisms so discharged at Chicago did not reach and are not contained in the organic matter in the waters of the Illinois river at Kampsville. (Palmer's testimony, Vol. 6, pp. 5655-6-7-8.) (E. G. Smith's testimony, Vol. 7, pp. 6828-9.)

Conditions on the Illinois river, prior to the opening of the canal, being such that there was practically no current, with a green scum forming upon the surface of the water during the greater part of the year, while since the opening there has been a decided current and no scum, assuming that the waters of the river both prior and before the opening were infected by typhoid fever dejecta and other contaminating products, the conditions obtaining before the opening of the canal would be much more favorable to the destruction of typhoid fever bacilli than

those conditions which obtained subsequent to the opening of the canal. (Mason's testimony, Vol. 7, 6965.)

Before the drainage canal was opened the typhoid death rate in the city of St. Louis was below the average of the experience of other cities of similar size in the United States,
221 and the city was recognized as having a reasonably good water supply, the death rate from typhoid fever being about 20.4 per 100,000 population. (See Fuller's testimony, Vol. 3, pp. 2608-9.)

It being an undisputed fact that typhoid fever germs are deposited in the Drainage Canal in Chicago through the sewers at Chicago, and it must therefore be shown by the testimony in the case beyond the possibility of doubt and with absolute assurance that such germs perish before reaching the intake of the St. Louis water supply at the Chain of Rocks.

The essential inquiry then is, how far may this particular germ travel in a running stream before losing its vitality. According to the experiments made by Dr. Ravold, it is shown to live in the laboratory under conditions which approach, as far as possible, those existing in the running stream, from 15 to 30 days. The distance that it may be conveyed therefore depends upon the longevity of the germ, together with the velocity of the stream flows.

In other words, as expressed by Dr. Ravold in his testimony, longevity and speed of the water constitute the prime factors in determining how far typhoid bacilli may be carried by the current of the stream.

(Dr. Ravold's testimony, printed record, volume 1, pages 480 and 792.)

It is a fact, as shown by the testimony, that the water from Lake Michigan flows to St. Louis within the life time of the

Bacilli Typhosus. In drawing conclusions and passing judgment upon the stream flow and the longevity of the germ, Dr. Ravold in his testimony spoke in no uncertain tone as to the ability of these germs reaching St. Louis from Chicago. He testified substantially as follows:

"Q. Now state in your opinion and from the examinations that you have made of the water in the DesPlaines river, the Illinois and Mississippi rivers, how long typhoid bacilli would live in the running water in going from Chicago to St. Louis?

A. Well, taking conclusions from the laboratory experiments, we find that bacteria will live from four days to as high as twenty-one days.

222 Q. That is in a flask?

A. In the laboratory flask, in living non-sterilized waters. Passing conclusion on them I am inclined to believe that the bacilli would live much longer in a running stream in living water than that period.

Q. How much longer

A. Anywhere from fifteen to thirty days, and that would be a very small limitation.

Q. A conservative estimate

A. A very conservative estimate.

Q. Now you spoke in reference to the period in which the bacilli would be vitalized and capable of producing disease when injected in the human system.

A. Yes, sir.

Q. You are speaking of the typhoid bacillus?

A. Typhoid Bacillus.

Q. Doctor, assuming that it requires the water 17 days to run from the sewerage openings at Chicago down the Chicago river to the canal, the canal to the DesPlaines river, the DesPlaines river to the Illinois river and thence to the Mississippi

river; the intake at the Chain of Rocks, and thence into the reservoir, when in two days thereafter it is distributed and used by the people of St. Louis, what would you say with reference to typhoid bacillus discharged in the Chicago Drainage Canal through the sewerage system of Chicago, finding its way into the water distributed to the people of St. Louis, as above described, and be sufficiently vitalized to produce disease, and taking into consideration your actual experiments with the typhoid bacilli in connection with the water in the various streams through which it would run?

A. Now the time consumed in traveling from Chicago of the sewerage would be seventeen days in the river to the intake and three days thereafter before being distributed to the people —twenty days. I think it highly probable from my experiments that typhoid bacilli discharged by the sewerage system of Chicago into the Drainage Canal would live and retain its vitality in the meanwhile entering the intake of the St. Louis water
223 works, and be distributed to the user of the water to be sufficiently vitalized to cause disease in a susceptible person.

Q. Now in connection with your answer to the last question and taking into consideration the great number of typhoid bacilli that come from the patient afflicted with the disease, and all other information that you possess on the subject—from the examination that you have made, what would you say with reference to the typhoid bacillus from Chicago finding its way into the reservoir and water supply of St. Louis?

A. Well, as I said before, I think it is highly probable that they could be carried into the intake and reservoir of the St. Louis water supply and retain their vitality meanwhile.

Q. Would they be sufficiently vitalized when found in the water supply of St. Louis to produce disease?

A. I think so. I would not like to try the experiment upon myself.

Q. State the length of time in your opinion typhoid bacilli would live in the waters running between the city of Chicago and the city of St. Louis, and being sufficiently vitalized when arriving in the water supply of the city of St. Louis to produce disease?

A. I said fifteen to thirty days. I thought I had answered that question. That is a conservative estimate.

(Dr. Ravold's testimony, printed record, volume 1, pages 807, 808, 809.)

On another point Dr. Ravold testified in this connection, as follows:

Q. Now, doctor, having carried out these experiments, having treated typhoid fever for twenty years, having been a Professor of Hygiene in the Washington University as a practical bacteriologist, I will ask you in your judgment if typhoid bacillus, coming from the out-falls of the Chicago sewers into the Chicago river and carried into the canal, could come into the Intake Tower of the St. Louis water works still retaining its vitality?

A. That will depend on the time that it takes the water to come from Chicago to St. Louis.

224 Q. Well, considering your knowledge of the flow?

A. Basing my conclusions upon the experiments that I have carried out and showing that the Mississippi and Illinois river water comes into the intake of the St. Louis water works, I believe that it is highly probable that a typhoid bacillus can live and be carried by the water from the Chicago sewers into the intake of the St. Louis water works, especially in the high water conditions of the Illinois river.

Q. Now, Doctor, does the speed of the water effect the life of the bacillus typhosus or typhoid bacillus. In other words, does the rapidity of the current tend to destroy the typhoid bacteria?

A. No, sir.

Q. Does the force of the water into which typhoid bacillus may be put effect in any manner its vitality?

A. No, does not kill it.

(Dr. Ravold's testimony, printed record, volume 1, pages 787-788.)

Again Dr. Ravold testified substantially on typhoid bacillus, as follows:

Q. Now from your knowledge as a bacteriologist and from the knowledge you have of the Chicago Drainage Canal, the DesPlaines river, the Illinois river, the Mississippi river and the distances, and the speed of the streams, can you state whether or not when the water is running through the Chicago Canal with the sewerage running into it, bacteria could come from the Drainage Canal into the Mississippi river?

A. Yes, sir. *I think the bacteriological experiments indicate that bacteria discharged by the Drainage Canal, especially in its high stages, are carried into the Mississippi river by way of the Illinois river.*

Q. Well, do you say that as a fact?

A. *Yes, sir.*

Q. Now, from the same state of facts above mentioned, as to the rivers, and the relative geographical location of the Illinois river, the Mississippi river and the Chicago Drainage
225 Canal, do you say or can you say whether or not the bacteria coming out of the Illinois river and being discharged into the Mississippi river, may or do enter the intake of the St. Louis water works?

A. I think they not only may, but they do, and I base this statement upon the bacteriological investigation that has been conducted by me from 1897 to the present time, from special experiments that were carried out which lead me to assert that they do from the mixture of the waters that takes place at the intake."

(Dr. Ravold's testimony, printed record, volume 1, pages 799-800.)

In 1894 the intake of the St. Louis water supply was removed from Bissell's Point to Chain of Rocks, and a comparison of the number of deaths from typhoid fever in St. Louis for the year 1895 to 1900, and five years prior thereto, shows a decrease of 125 per cent less since the removal of the intake to the Chain of Rocks than during the five years immediately before.

(Dr. Ravold's testimony, printed record, volume 1, pages 760.)

For the three years prior to the opening of the Drainage Canal, to wit, 1897, 1898 and 1899, there were 1807 cases and 350 deaths from typhoid fever in St. Louis.

For the three years next following the opening of the Chicago Drainage Canal on January 17th, 1900, there were 3426 cases and 588 deaths in St. Louis, showing an annual increase of 68 per cent.

(Dr. Ravold's testimony, printed record, volume 1, pages 761-762.)

In November, 1899, a few months before the Drainage Canal was opened, there appeared to be an increase of deaths in St. Louis from typhoid fever. This increase is explained by Dr. Ravold as follows:

"I have looked over the health statistics. In 1899 we had a remarkable number of cases in November; 488 cases were

226 reported and 31 deaths. In December, 116 cases and 20 deaths. It was ascertained at this time, in fact I saw the men at work. The river was so low in 1899 that it was feared by the Water Commissioner that the lowest gate in the Intake Tower would not be low enough to admit enough water for the pumps, so a coffer dam was built about the intake and men put to work breaking a hole through the tower for the purpose of putting in a gate. The work at the intake out in the river on the east side of the tower as low down as they could go, so as to have a very low gate for low water periods. They went down to the bottom of the river and stirred things up pretty well. They worked at the bed of the river and stirred up the mud. The stirring up of the silt and mud in the bottom of the river where it had settled at the bottom of the Intake Tower had the effect to stir up any typhoid or pathogenic bacteria in the water. At the same time there was dredging going on in the Illinois river at Kampsville. They were digging out a channel for boats, digging out the bottom of the bed of the river. This of course caused such large quantities of mud and silt to be abstracted from its resting place at the bottom of the river and carried off down the stream."

(Printed record, volume 1, pages 764-765.)

With reference to the highest number of typhoid fever cases recorded and the lowest number recorded in the year 1900, there is a relation existing between the percentage of Mississippi river water, as shown by this map, going into the intake of the St. Louis water works.

In the early part of the year from February 6th, 1900, the quantity of water estimated by total solids in the Mississippi river increased at the intake and reached 100 per cent on February 8th, 1900, or 21 days after the Drainage Canal was opened.

The period of incubation of typhoid germ is from six days to three weeks.

There is also a relation, as shown by the map, between the rise in the number of typhoid fever cases at St. Louis and the rise in the percentage of the water of the Mississippi river entering the intake at this particular time.

227 During this period 100 per cent of Mississippi river water entered the intake, it not being mixed with Missouri river water, and on March 3, 1900, there was an increase in the typhoid fever cases. From February 8th to March 3rd, 23 days, it was then that the deaths from typhoid fever increased to assert itself and continued until March 17th. The Missouri river in the meantime having increased in volume, the amount of the Mississippi river water entering the intake March 17th having fallen to 12 per cent, so that there was a gradual increase of typhoid fever in St. Louis from March 3rd to March 17th, and from March 24th to April 7th, corresponding with the percentage of Missouri and Mississippi river water entering intake during the period from February 8th, when it reached 100 per cent, and from that day gradually fell until on the 15th of February it was only 12 per cent.

(Printed record, volume 1, pages 439-444.)

It will be well to note that this period was immediately after the opening of the Drainage Canal.

The evidence shows that typhoid fever increased with the water of the Mississippi river mixing with the water of the Illinois river flowing into the intake.

(Printed record, volume 1, page 447.)

Typhoid fever conditions in St. Louis in the month of March, 1900, became almost epidemic. Within the incubation period, after the opening of the canal of the passage of the water from Chicago to St. Louis, the typhoid fever death rate ran up very rapidly, and in March 117 cases were reported and 16 deaths. A phenomena that never had occurred in the existence

of St. Louis, Missouri. No such flare of typhoid in March has ever been recorded in the history of the city, as followed this mixture of the waters of the Illinois and the Mississippi river at the intake.

(Printed record, volume 1, page 837.)

We have seen that the percentage of the Mississippi river water entering the intake during the month of March, 1900, reached as high as 100 per cent, and during the period from the opening of the canal until the 28th of May, the percentage of the Mississippi river water entering the intake rose and fell from May 28th until June 29th, when it again arose to 39 per cent. On August 31st the percentage again reaches 50 per cent. During all of the periods enumerated the number of typhoid cases at St. Louis was increasing with the increase of the Mississippi river water entering the intake at low stages of the river.

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This comparison is true throughout the entire period of this investigation.

(Dr. Ravold's testimony, printed record, volume 1, pages 446-447.)

The effect of the increase quantity of Mississippi river water entering intake at St. Louis increased the typhoid fever deaths at St. Louis for the year 1900 over that of 1899, as shown by a comparison of the deaths from this disease in the respective months of the two years.

(Dr. Ravold's testimony, printed record, volume 1, page 448.)

(See also Complainant's exhibit No. 10.)

The typhoid mortality records of the principal cities and towns on the Illinois, Mississippi and Missouri river watersheds

were obtained where it was possible to do so, from 1893 to 1902, inclusive. This investigation disclosed no permanent increase in any locality so as to account for the increased number of deaths in St. Louis since January, 1900. This investigation resulted in the following data being obtained:

Deaths reported from typhoid fever in cities lying tributary to the Illinois river, exclusive of Chicago.

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
Peoria				13	18	18	12	33	15	18
Bloomington	12	14	15	9	10	10	9	15	9	15
Springfield										
Ottawa	2	5	2	2	4	4	3	3	5	2
Decatur	5	7	2	1	7	5	7	11	5	4
229										
Joliet	12	14	*	12	12	15	15	13	13	21
Pekin										
Elgin	5	3	5	14	8	4	5	15	15	8
Aurora	6	12	19	10	5	10	4	17	11	2
Havana										
Totals	45	62	45	66	56	66	55	129	85	82

*No record.

Deaths reported from typhoid fever in the following cities, according to the public records:

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
St. Paul	51	32	38	37	22	43	30	36	24	23
Minneapolis	134	107	88	60	148	86	71	79	121	66
Red Wing, Minn.	5	2	2	3	2	4	3	3	2	3
Winona, Minn.	2	2	1	2	2	2	5	5	1	4
La Crosse, Wis.	15	2	5	0	3	8	7	7	5	4
Dubuque, Ia.	6	6	12	8	12	10	12	7	8	10

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
Clinton, Ia.	10	5	3	7	5	7	7	10	12	5
Rock Island, Ill	15	13	3	13	15	15	10	14	28	5
Moline, Ill.	7	9	8	11	3	5	20	22	16	7
Davenport, Ia.	5	6	4	3	5	2	12	14	11	11
Muscatine, Ia.	4	8	5	5	2	25	2	13	8	5
Burlington, Ia.	8	10	8	13	3	4	8	13	12	11
Fort Madison, Ia.										
Keokuk, Ia.	8	14	3	3	7	10	9	10	4	7
Quincy, Ill.	22	33	24	13	15	6	7	9	12	18
Hannibal, Mo.	7	7	6	8	10	8	4	3	3	2
Louisiana, Mo.										
Des Moines.	22	29	30	14	20	17	13	7	22	21
Yearly totals	321	285	240	200	257	237	217	261	291	210

Deaths reported from typhoid in cities on the Missouri river watershed:

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
Lincoln, Neb.	33	21	23	15	14	12	13	4	13	10
Omaha	22	40	29	18	22	32	26	24	23	20
Council Bluffs	5	7	6	8	8	6	8	11	6	8

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
230										
St. Joseph, Mo.	20	22	31	19	15	19	37	20	12	13
St. Charles, Mo.							22	5	6	14
Kansas City, Mo.	59	37	34	29	38	49	52	49	58	58
Jefferson City										16(?)
Totals	139	127	123	89	97	118	158	113	118	139

Total number of deaths reported from typhoid fever in cities lying tributary to the Mississippi, Missouri and Illinois rivers, respectively:

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
Mississippi	321	285	240	200	257	237	217	261	291	210
Missouri	139	127	123	89	97	118	158	113	118	139
Illinois	45	62	45	65	56	66	55	129	85	82
Total	505	474	408	354	410	411	430	503	494	431

DEATHS IN CHICAGO AND ST. LOUIS.

Chicago

1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
1008	1997	1489	670	491	518	751	437	636	442	339	509	801

St. Louis

1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
277	160	488	215	178	106	106	125	95	130	168	198	222

(Record, Vol. 7, pp. 6901-3.)

The cities of St. Charles and Jefferson City on the Missouri river watershed; Springfield, Pekin and Havana on the Illinois, and Fort Madison, Louisiana on the Mississippi should not be considered for the reason that full and complete data could not be obtained as to them.

The foregoing affords no reason, excuse or cause for the increase at St. Louis subsequent to January, 1900.

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20.

THE DAMS IN THE ILLINOIS RIVER AND THEIR EFFECT.

There are five dams constructed across the Illinois river. Three were built by the State of Illinois, and two by the United States Government for the purpose of aiding navigation. Before the drainage canal was opened the water behind the dams for a distance of fifty or sixty miles would, during the greater part of the year, obtain a quiescent state, which materially aided the self-purification of the water in the stream, in as much as stagnant water purifies itself more rapidly than running water. Sedimentation was added, and every possible advantage given the river to purify itself. Since the opening of the drainage canal the dams have been of little or no service in this regard. As the testimony shows, the water flows down the river and over the dams in a constant and continuous current, and while these dams may have furnished sedimentation basins, so to speak, before the canal was opened, and may be regarded to some extent as aiding sedimentation today, yet the continual changing in the flow of the stream and body of water picks up sediment and carries it over the dams and on down the river. Since the opening of the canal the water is known to flow continuously, and requires only an average time of ten to fifteen days to pass from the sewers of Chicago to the city of St. Louis.

(Williams' testimony, Vol. 3, pp. 3324 to 3326.)

So far as the dams produce slack water or quiescence, self-purification is favored, but if sedimentation or sludge is allowed to remain in the stream and only removed artificially, the chances are good, as experience shows, that in freshets it will be

returned to the stream and again become a part of it and travel with it and produce trouble below. This has been the experience of cities such as Newburyport, Lowell and Lawrence. (Sedgwick's testimony, Vol. 3, pp. 2218-19.)

232 The general effect of dams is to hold back the water and produce slack water basins, especially when the dams are high enough to check the flow entirely, or essentially. And any checking of the flow or slowing of the stream, other things being equal, favors sedimentation and the disappearance, from the waters, of the infectious material. "The sanitary significance of this is, as I have already stated, extremely interesting and important. The carrying down of the germs of infectious diseases and the longer or shorter detention of them in the sediment in the first place removes them from the moving water, or tends to remove them, and in the second place by detaining them gives them an opportunity to die out more or less. These factors of sedimentation and storage are, in my judgment, the principal factors in the so-called self-purification of streams. On the other hand, it must be carefully kept in mind that streams are subject to scouring more or less frequently and that the disappearance of infectious materials is not necessarily their destruction. A considerable increase in the flow of such a stream as the Illinois river must tend to favor the return to the stream of some of the materials which have been previously deposited in it. The wind, even, may cause sediment to be stirred up, especially where the water is shallow. It is a well-known fact that Lake Erie is so easily disturbed by winds as to bring up sand from the bottom and interfere with the use of the water at Buffalo for drinking purposes. (Williams' testimony, Vol. 3, page 2386.)

21.

POPULATION OF THE WATERSHEDS OF THE RESPECTIVE RIVERS WITH, AND EXCLUSIVE OF THE POPULATION OF THE SANITARY DISTRICT OF CHICAGO, TOGETHER WITH THE AREA OE THE DRAINAGE BASINS OF EACH.

According to the report of Jacob A. Harmon, found in the report of the Illinois State Board of Health on the sanitary condition of the Illinois river, and its tributaries in 1901, at
233 page 119, it is stated that the total rural population of the Illinois drainage basin in the year 1900 was 893,723, the urban population of the Illinois river, exclusive of the city of Chicago, in 1900 was 616,664, the area of the Illinois river basin being 27,914 square miles. (Whipple's testimony, Vol. 3, pp. 2131-2.)

Considering cities having a population of 25,000 or over, according to the census of 1890, the increase of population naturally resident upon the watershed of the Mississippi river above the Chain of Rocks caused by the addition to the population of the Sanitary District of Chicago, speaking generally, has been about doubled. If we consider the population of cities having more than 4,000 population situated upon the watersheds of the Missouri river, Mississippi river and Illinois river, above the Chain of Rocks, but not including the population of Chicago, and if we add to this the population of Chicago, the increased population for the entire watershed of the Mississippi above the Chain of Rocks would be about 63 per cent. In that connection it would be well to state as a general proposition that it is customary for sanitarians to consider that the amount of sewage

pollution in streams may be approximately estimated by taking the total population of towns on its watershed having a population of four thousand inhabitants or over.

(Whipple's testimony, Vol. 2, pages 1988-89-90.)

As a general rule, the urban population is very much more dangerous than rural population; expressed in figures, it would probably be fair to say that the urban population was at least ten times as dangerous as the rural. The reason for this is that urban populations are more often sewered, and when not sewered are more often upon streams, while the rural population is very often remote from streams, almost always without sewers, and even if the same infection occurs in a rural family as in an urban family the chances of keeping that infection within the family and on the place are far greater than they are in the case of an urban population. It is, therefore, obvious, as a general proposition, that the rural population is of comparatively little importance in this respect, it being the urban
234 population that we have chiefly to consider. By the opening of the drainage canal the sewage from the urban population tributary to the watersheds of the Mississippi river as it flows to the intake tower of the St. Louis Waterworks, has been increased about 63 per cent. The urban population on the watershed of the Mississippi river and its tributaries above the intake of the St. Louis Waterworks, exclusive of the Sanitary District of Chicago, based upon the population of towns having more than four thousand inhabitants, is 2,695,782; in other words, this population may be divided as follows: On the watershed of the Missouri river, 1,090,832; the upper Mississippi river, above the mouth of the Illinois, 1,219,645; upon the Illinois river, exclusive of Chicago, 385,305, making the total, as above stated, 2,695,782. (Sedgwick's testimony, Vol. 3, pages 2235-6.)

In answer to the question as to whether he had made an estimate of the approximate number of persons sewering into the Mississippi river, exclusive of the Sanitary District of Chicago, Mr. Fuller (Vol. 3, p. 2616) made the following answer:

"I have looked into this matter, and in round numbers place the figure for those people who sewer directly into the Mississippi and its branches and tributaries above the St. Louis Water Works and exclusive of the Sanitary District, at about 2,700,000. This figure is based upon a separation, on an average of the sewage contributing population from the rural population by taking towns of 4,000 and over as representing those who have sewerage systems and contribute sewage directly to the water courses. Some of the towns of more than 4,000 population are undobutedly not provided fully with sewerage facilities. On the other hand, there are quite a number of towns of less than 4,000 population which in a limited measure do have water works, and do have some sewerage. Looking at this question as a practical proposition, it is my judgment that the amount of the sewage contributing population in towns of less than 4,000 inhabitants no more than off-sets in the aggregate the amount of population in the cities larger than 4,000 inhabitants which do not have sewers. It is a fact well known among practical water works and sewerage people that the number of miles of water-mains in a town ordinarily exceeds to a considerable
235 degree the number of miles of sewer lines. In making this statement as to the number of people in the aggregate sewering into the Mississippi river above the Chain of Rocks intake, I include of course the Missouri river and the Illinois river, exclusive of the Chicago Sanitary District, as well as the upper Mississippi."

"Q. Mr. Fuller, why did you draw a line at the towns of 4,000 inhabitants for the separation of population contributing pollution directly from those which contribute indirectly?

"A. Well, that matter I took up pretty thoroughly in the last answer I gave, and will state that the basis as described in my last answer is the result of my experience and I think that on the whole it is a reasonable and fair method due to its compensation of the two factors: First, the amount of population in the cities above 4,000 which do not sewer directly into the river, and secondly, the population of some towns of less than 4,000 which do contribute sewage directly to the water courses.

"Q. Mr. Fuller, what would you estimate to be the percentage of increase in population sewering into the Mississippi river valley above St. Louis, due to the Chicago Drainage Canal bringing sewage of Chicago into the Mississippi river watershed?

"A. In round numbers I estimate an increase of 60 per cent."

TRIBUTARIES OF THE ILLINOIS RIVER AND THEIR SANITARY CONDITION.

The testimony on both sides of the case shows that the sanitary condition of the tributaries of the Illinois river is far better than the sanitary condition of the Illinois river itself, thus going to show that while the immense pollution of infectious material coming down the Illinois river can be accounted for to some extent from the pollution in its tributaries, yet from the fact the tributaries are in better sanitary condition than the river is, we reach the conclusion that the major part of the infectious material is derived from some source other than its tributaries, and, in fact, chemical and bacteriological analyses point to the 236 drainage canal as the only source from which this increased pollution can be derived. (Keiser's testimony, Vol. 2, pp. 1140-1-2. Teichmann's testimony, Vol. 2, page 1175.)

22.

THE PHYSICAL CONDITION OF THE ILLINOIS RIVER BEFORE THE CANAL WAS OPENED COMPARED WITH THE CONDITIONS SUBSEQUENT TO THE OPENING OF THE CANAL.

The testimony taken upon the part of the defendants from witnesses who lived upon the Illinois river from its source to its mouth shows beyond question that, prior to the opening of the drainage canal, during the greater portion of the year it was in, what might be called, a septic condition. The current was very slight and at times none at all. Above the respective dams the river assumed the appearance of a green field, being covered with a green scum or algae formation. A canoe or skiff would separate this scum and leave an open path for some distance behind.

The opening of the canal caused an increased volume of water to pass down the river, consequently increased the velocity or speed and carried the nitrogenous matter with the current, which prevents the formation of the algae or scum; in other words, since the opening of the canal the river has not purged itself of the polluting material deposited into it, not having sufficient time to oxidize or destroy the material deposited in it. It has passed out of the Illinois river at its mouth into the Mississippi.

Two miles above the mouth of the river at Grafton, the testimony shows the river to have been in the condition above described. (See Calhoun's testimony, Vol. 3, pp. 2914-16-17.) (See also, D. J. Shoemaker, Vol. 3, pp. 2940-1-2; J. M. Allen, Vol. 3, pp. 2950-1; Wesley Park, Vol. 3, pp. 2955-6; E. Meysenberg, Vol. 3, p. 2960; Daniel Heath, Vol. 3, p. 2960.)

At Hardin, eight miles above Grafton, the same conditions obtain as at Grafton. (See testimony of Chas. Flamm, Vol.
237 4, p. 2995; Nathaniel Bull, Vol. 4, p. 3001; M. E. Fisher, Vol. 4, p. 3001; Albert Park, Vol. 4, p. 3008; Dr. Barry, Vol. 4, p. 3012; George Adderton, Vol. 4, p. 3032.)

So also at Kampsville the same conditions exist. (See C. B. Bakerville, Vol. 4, pp. 3054-5; Ed Heaton, Vol. 4, p. 3060; Thomas Myers, Vol. 4, p. 3064; I. Davidson, Vol. 4, p. 3069; Walter Mapin, Vol. 4, p. 3118.)

C. B. Bakerville, on page 3054 of his cross-examination, volume 4 of the record, describes the conditions before and after the opening of the canal as follows:

"Q. What is the difference between the current or flow of the river now and what it was prior to the opening of the Chicago Drainage Canal?

"A. Well, we have a good deal changed current.

"Q. How far is it from where this boat is on which we are taking testimony down to the dam?

"A. Something like half a mile.

"Q. This current you speak of continues down, on and over the dam, does it not?

"A. Yes, sir.

"Q. What is the stage of the water in the Illinois river at this point as compared with the ordinary stage of the water?

"A. Well, it is some lower right now than it has been for several years; that is, the last two or three years."

It will be observed from this testimony that the water passed in a rapid current over the dam at Kampsville, and what is true with reference to conditions at Kampsville is also true with reference to all of the dams on the river.

Ira Davidson, at page 3069 of his cross-examination, replied as follows:

"Q. What is the stage of the river at Kampsville now as compared with what it has been ordinarily since the opening of the canal in January, 1900?

"A. Well, it is rather low at present.

"Q. Has it been much lower since the opening of the canal than it is now?

238 "A. Well, year before last, yes, sir.

"Q. That was in the drouth of 1901?

"A. Yes, sir.

"Q. There is a good current in the river now, is there?

"A. Yes, sir.

"Q. A good current here in the river at Kampsville?

"A. Yes, sir.

"Q. That current continues from here to the government dam, about one-half a mile below?

"A. Yes, sir.

"Q. And grows stronger as you go up the river away from the dam?

"A. The farther from the dam you get the stronger the current."

At Gravel Point the same conditions were shown to exist. (See testimony of D. J. Nelson, Vol. 4, p. 3159; Thomas Carter, Vol. 4, p. 3160; George Nelson, Vol. 4, p. 3164; S. D. Thurston, Vol. 4, p. 3165.)

In fact, the same conditions, prior and subsequent to the opening of the canal, existed in Pearls, LaGrange, the lock at LaGrange, Preston, Havanna, Peoria, Pekin, Chillicothe, Henry, LaSalle and other points. (See testimony of J. J. Kerr, Vol. 4, p. 3243; L. W. Gooddell, Vol. 4, p. 3263; O. H. Harpham, Vol. 4, p. 3290.)

The defendants have undertaken to show that the great pollution contained in the Illinois river at Grafton is caused principally by the sewage discharged from the cities of Pekin and Peoria. This, however, is of no consequence when taking into consideration the relative number of people residing at the two places as compared to the population of the Sanitary District of Chicago.

The contention is also made that large quantities of decomposing matter is discharged into the river at these points on account of the distilleries, manufacturing plants and the feeding of cattle. The evidence, however, discloses that at both Pekin and Peoria there are a less number of cattle being fed now than prior to the opening of the Drainage Canal; in other words,
239 since 1899 the number has decreased materially. According to conditions that existed at Peoria for several years prior to 1900, an average of 25,000 head of cattle were fed per annum, while subsequent to that time the average has fallen to less than 10,000. According to the testimony of Robert D. Clarke, a distiller at Peoria (Vol. 4, p. 3670), not more than one-fifth of the cattle are fed at Peoria now as compared with the conditions existing prior to 1899.

An effort was also made to show that a floating population resided upon the banks of the Illinois river at Peoria, which is stated by counsel for the defendants in some of their hypothetical questions to be about 3,000; yet the fact is, as shown by the testimony of Robert D. Grayson (Vol. 4, p. 3523), this population, prior to the opening of the canal, amounted to about 500, and that since the opening of the canal it has been reduced to about 400, so that the conditions existing upon the Illinois river at Pekin and Peoria have materially improved since January 17th, 1900. So the increase in typhoid fever due to the increased pollution in the river cannot under these circumstances be attrib-

uted to Peoria and Pekin. (See testimony of C. F. Barstow, Vol. 4, p. 3587.)

See, in fact, the testimony of all of the witnesses relating to conditions existing upon the Illinois river prior and subsequent to January 17th, 1900.

23.

THE VELOCITY OF THE ILLINOIS RIVER HAS BEEN INCREASED SINCE JANUARY 17th, 1900, DUE TO THE OPENING AND OPERATION OF THE CHICAGO DRAINAGE CANAL, AND THE INCREASE CONSTITUTES AN ADDED DANGER TO THE PEOPLE OF ST. LOUIS AND MISSOURI.

By the addition of 250,000 to 300,000 cubic feet of water per minute through the canal into the Des Plaines and Illinois rivers, the current of the river has been increased so that the time necessary for pathogenic bacteria to pass from Chi-
240 cago to St. Louis has been largely decreased. The addition of such a volume of liquid as passes through the Drainage Canal must necessarily quicken the flow of the Illinois river, and therefore hinder the effective sedimentation, and by this shortening of the time required for the infectious germs to pass through the river, interfering with their detention, aggravates the danger of their arrival at the mouth of the river. It would not only carry the sewage from Chicago to St. Louis with rapidity, but by increasing the flow it would quicken the passage of the sewage or infectious pollution from Peoria and other points to the mouth of the Illinois river and thus mingle them with the waters of the Mississippi river This increase in the speed of the current of the Illinois river by the added water of the drainage canal would have the effect to increase the liability to typhoid and other water borne diseases on the part of the inhabitants of St. Louis and the State of Missouri using the water of the Mississippi below the mouth of the Illinois river for drinking and domestic purposes. (Sedgwick's testimony, Vol. 3, page 2195.)

So that the Illinois river, polluted and infected by the sewage from the Sanitary District of Chicago since the opening of the Drainage Canal by being forced down the river on account of the increased volume of water coming from Lake Michigan, has rendered less safe the water supply of the city of St. Louis, drawn at the intake tower at the Chain of Rocks, than it was prior to January 17th, 1900. (Sedgwick's testimony, Vol. 3, page 2224.)

24.

THE INCREASE IN TYPHOID FEVER IN ST. LOUIS SINCE 1899 HAS NOT BEEN DUE TO INFECTED WELLS OR MILK.

In his cross-examination Prof. Sedgwick, at page 2342, stated that as an expert in determining the source of typhoid infection, consideration should be given to all local conditions, and
241 reasonable search should be made for the purpose of determining the condition of wells out of which water might be used as well as the condition of the general water supplies. In this connection, speaking with reference to the condition of the wells in St. Louis, he stated there were about 3,000 wells in St. Louis and said, "I have considered the question of whether such a number was materially changed before and after. I have used my general knowledge of American communities and their behaviour in regard to wells and water supply. I have taken into account the typhoid fever and the characteristics of the population as nearly as I could ascertain them by inquiry and observation, and I have come to the conclusion that there is no reason to suppose that any material change in the habit of people in regard to the use of such wells or well water since the time mentioned has occurred, and that therefore that element may be entirely excluded as of consequence in causing any portion of the typhoid increase in St. Louis. I might even go further and say as between wells taken in a general way and including a certain number of polluted wells, and a city water supply not above suspicion, it is by no means clear to my mind that the use of such wells would increase the typhoid fever rate over and above the use of a water supply which is not entirely pure. I therefore exclude altogether the wells in St. Louis as

producing an important part of the increase in typhoid fever since January 1st, 1900. I consider the information which I have received and which I now have upon the subject sufficient to establish my conclusion beyond all reasonable doubt."

The city of St. Louis is divided into seven sanitary districts, numbered one to seven, inclusive. In district number one there are four hundred and ninety-two wells; district number two, ten hundred and seventy-three wells; district number three, one hundred and one well; district number four, ten hundred and fifty-eight wells; district number five, three hundred wells; district number six, three hundred and eleven wells; district number seven, eighteen hundred and seventy-seven wells.

The typhoid death rate for the respective years in the respective districts was as follows: District No. 1, 1900, 19
242 deaths, 1901, 19 deaths; 1902, 26 deaths; District No. 2, 1900, 14 deaths; 1901, 27 deaths; 1902, 21 deaths; District No. 3, 1900, 28 deaths; 1901, 30 deaths; 1902, 36 deaths; District No. 4, 1900, 24 deaths; 1901, 27 deaths; 1902, 34 deaths; District No. 5, 1900, 18 deaths; 1901, 18 deaths; 1902, 23 deaths; District No. 6, 1900, 42 deaths; 1901, 46 deaths; 1902, 57 deaths; District No. 7, 1900, 23 deaths; 1901, 30 deaths; 1902, 25 deaths.

It will be observed from the foregoing table that for the three years, 1900, 1901 and 1902, District No. 6, containing only 311 wells, had one hundred and forty-five deaths from typhoid fever, while District No. 7, containing 1877 wells, had 78 deaths from typhoid fever, and this comparison holds good throughout all the districts. (See Sedgwick's cross-examination, Vol. 3, pp. 2350, 2351.)

In this connection, Prof. Sedgwick stated: "There is absolutely no reason to suppose that a different condition prevails in the wells of the city of St. Louis since January 1st, 1900, than that which had prevailed there for years before, and I should

regard it as absolutely impossible and absurd to attribute the excess of typhoid fever which has appeared in St. Louis since January 1st, 1900, to any such source. (See Sedgwick's testimony, Vol. 3, page 2356.)

In reference to typhoid fever from contaminated milk, Prof. Sedgwick made this statement:

"If the route of a dairyman covered the whole city, or any considerable part of it, it is possible that an infection might be spread from such source, but any epidemic produced in that fashion, of an appreciable size, is usually easy to discover, and there are none of the ear marks of an epidemic as far as I have been able to discover about the typhoid fever deaths in the city of St. Louis during the years 1900, 1901 and 1902. (See Sedgwick's cross-examination, Vol. 3, page 2352.)

25.

THE DOCTRINE OF SELF-PURIFICATION OF STREAMS DISCUSSED.

243 It is admitted by all the expert witnesses that so long as disease producing germs may live in water of running streams, the water may not be considered as having become purified from infectious material discharged into it from a point above, and the life of disease producing organisms depend largely upon the character of the flow and the amount of pollution and infectious material discharged into it. Dilution has a tendency to increase the longevity of organisms, and it is believed by some that oxidation and aeration also increases the opportunities for the life of pathogenic bacteria. Upon this subject Prof. Sedgwick, Vol. 3, page 2191, said, in answer to the question as to whether or not running water will purify itself so as to be free from pathogenic bacteria that may have been deposited in it, "In this whole matter of self-purification of streams we have today very different ideas from what we had twenty years or thirty years ago. In trying to answer the question specifically and closely—if I try to answer specifically and closely—I shall have to say that running water under some conditions might very largely and possibly even altogether purify itself from infectious germs, but these conditions would have to be very unusual, and so unusual as to be practically theoretical, or virtually theoretical. It was formerly believed by experts that running water readily purifies itself. That belief has been abandoned. Acting upon that belief, which was the best state of our knowledge twenty or thirty years ago, the numerous cities of the United States put in water works which should derive water from streams into which sewage was poured at points above. That

was the best art of the time, and engineers, chemists and sanitarians agreed about it. In the city of Pittsburg, for example, which I have especially studied, the water supply was introduced from the Allegheny river with the confident belief that such sewage as might find its way into the river at points above
244 would be effectually removed before the citizens had access; in other words, before the water came to the citizens. That belief has been found to be erroneous. Pittsburg suffers today by typhoid fever perhaps more than any other city of the United States, certainly excessively. The cities on the lakes, Niagara Falls, Buffalo, Cleveland, Detroit, Chicago, Milwaukee and Duluth take water supplies subject or exposed to contamination by sewage, and are today considering the possibility of abandoning such supplies, owing to the failure of self-purification of sewage. Nevertheless there is a large measure of self-purification of streams. There is at times in certain streams, especially a large measure of self purification. The object is a complex and difficult one, and the tendency of opinion has been to increase our distrust in the efficacy of self purification of water or sewage. Three or four years ago I examined this subject carefully, and arrived at the conclusion which I stated in a book published a year ago, before I had any expectation of connection with this case, which gave substantially the same point of view that I have stated, which I should be glad to read if it is proper. 'Today we realize that this theory of purification is only half true, and that such self-purification is only partial and absolutely unreliable. By a curious reversal of scientific opinion, we now hold that it is precisely running water which is least likely to purify itself, while stagnant or standing water, formerly looked upon with dread and suspicion, is now in much favor. The old theory was in vogue long enough to enable us to make a wonderful series of experiments, and on a stupendous scale;

experiments in which whole cities confidingly used for years sewage polluted water, often with sad results, but results of lasting instruction to mankind. Never again so long as civilization endures, will intelligent communities, acting under expert advice, repeat these sad experiments.' " (Sedgwick's testimony, Vol. 3, page 2193.)

Further on, Prof. Sedgwick said:

"I have given some attention to typhoid fever in Chicago, and I have also given attention to the condition of affairs at Detroit, Cleveland, Buffalo and Niagara Falls, and I found
245 in Buffalo, rather to my surprise, a prevailing feeling among medical men that the time was at hand when Buffalo has got to purify her water because of the pollution put into the lake at Cleveland and higher points. I found that at Niagara Falls they were suffering severely from typhoid fever, which the physicians there, who were present at my lecture, freely expressed themselves as believing to be derived from the sewage of Buffalo, which had run down the Niagara river. I think it is a great question whether the big lakes, or rather the people who are using the big lakes, have not got to give up the use of them after awhile. A while ago Prof. Jordan reported practically to that effect for Chicago, and Detroit certainly stands in great danger from pollution at Port Huron and possibly other points, and Cleveland, I have been told, though I am not sure of this, is seriously thinking of giving up its tunnels and going into filtration because the water that comes down from above is polluted, and the whole question of the extent of pollution of water supplies and the life of the typhoid germs—typhoid and other disease germs in water, is today a very seriously debated question, and as I said this morning, the growth of opinion is more and more towards the idea that it will not do to trust to

self-purification provided you have got upon your watershed a very heavy or extensive pollution."

"I may say right here, and in this connection we might as well be done with this once for all. We used to think that running water, when it got thoroughly aerated, purified itself, especially if it came from long distances. That was the theory on which Pittsburg put in its water works. That was the theory upon which Lowell took the obviously sewage polluted water of the Merrimac and used it for water supply purposes. It was one of the commonest things that chemists and sanitarians believed, and they had reason to believe at that time, that running water from even moderate distances would so purify itself as to be safe; but Pittsburg, Lowell and Lawrence, and so far as I know, nearly all of the cities that have trusted to that, have been typhoid ridden, and today, as I reported at Pittsburg, the distance of 100 miles, or even more remote points, infection coming from Oil City, 113 miles, or even more remote
246 points, may produce typhoid fever. It is not today so much a question of distance; it is the question of giving time for the germs to settle out and die out, and it is dilution and time of quiescence, particularly quiescence. It is simply a question of time. You have got to eliminate all idea of distance from these things, and bring in the question of time largely, and that it was I stated in my treatise on Sanitary Science and Public Health written two or three years ago. It is nothing that I have gotten up for this case, or anything of that kind. It is a fact that is borne in upon me by long experience, and I believe that in that respect I stand entirely square with the sanitarians of the world.

"The amount of infectious pollution does not affect the time needed but the degree of danger. The amount of infectious pollution affects the degree of danger; it would not affect the time, that is the time for each individual microbe. Of course, that is

its own individual problem. One microbe coming down from Chicago and resting quietly in the slack water of the Illinois, if it lay there long enough would probably die out, I would say must certainly die out if it lay there long enough. Of course, some one might not agree with me on that, but I think so. But, of course, if a million came down the chances that some might be carried on by a little freshet, or something of that kind before they had died out, would be greatly enhanced, and other things being equal, the larger the infection the more serious the danger.

(Sedgwick's evidence, Vol. 3, pp. 2211, 2212.)

FACILITIES FOR SELF-PURIFICATION IN THE ILLINOIS RIVER WERE BETTER UNDER THE CONDITIONS EXISTING PRIOR TO OPENING OF THE CANAL THAN UNDER THE CONDITIONS WHICH HAVE EXISTED SINCE THE OPENING.

Prior to the opening of the Drainage Canal, the Illinois river was a slow, sluggish stream, and during the greater part of the year there was practically no current in it. A chunk, or block, thrown in the water above any of the dams of which there are five, would remain quiet unless carried one way or the other
247 by the force of the wind. During a great part of the year the water was covered with a green scum, showing that putrefaction and self purification was in progress. Since the drainage canal has been opened there has been a constant, continuous and strong current of water passing from the source of the river to its mouth. Its facility for septic operation has been destroyed. Based upon modern discoveries, the quiescent state is conducive to self-purification of water, and that a moving body of water has the tendency to prolong the life of pathogenic bacteria contained in it. Less bacteria are now perishing in the waters of the Illinois river than prior to the opening of the

canal, even though it be considered that large quantities were deposited therein during both periods.

(Sedgwick's testimony, Vol. 3, page 2193.)

The increase made in the speed of the current of the river by the addition of the water of the Drainage Canal, which necessarily increases the current, has the effect of increasing the liability of typhoid and pathogenic bacteria passing down the river to reach the Mississippi, and consequently has had the tendency to increase typhoid fever among the people using water for domestic purposes.

(Sedgwick's testimony, Vol. 3, page 2196.)

Before the canal was opened the facilities for sedimentation were exceedingly great in the Illinois river, and since that time, by the increase in rate of flow, pathogenic bacteria are carried in large quantities directly through the canal, through the Des Plaines and Illinois rivers to the Mississippi.

(Sedgwick's testimony, Vol. 3, pp. 2197, 2219, 2220, 2221; Whipple's testimony, Vol. 3, pp. 2085, 2086, 2087, 2088; Keiser's testimony, Vol. 2, pp. 1045 to 1049.)

26.

THE DANGER TO THE PEOPLE OF ST. LOUIS AND MISSOURI CAUSED BY THE OPENING AND OPERATION OF THE CHICAGO DRAINAGE CANAL IS ACUTAL, CONSTANT, IMMEDIATE AND CONTINUOUS.

248 The chemical and bacterial analyses of the water in the Illinois and Mississippi rivers show that the opening of the drainage canal and its operation since January 17, 1900, has at all times rendered the waters of the Mississippi river at the Intake of the St. Louis water supply unsuitable for domestic use, while prior to that time it is shown to have been a reasonably safe water. By the addition of a population of over two millions of people to the watershed of the Mississippi river, and subjecting the Mississippi river to additional polluted water from the canal and the sewage of the added population, it is evident that the velocity or stream flow of from ten to fifteen days required for the water to pass from Chicago to St. Louis, not only renders the water unsuitable for domestic purposes, but constitutes a constant, immediate and continuous danger to the people of St. Louis and of the State of Missouri using the water of the Mississippi river below Grafton for domestic purposes. In this connection Prof. Sedgwick stated as follows:

"I believe that the danger is practically constant, by which I mean that it can never be known at what moment infectious material may arrive from the sewers of Chicago. I do not suppose that such material is arriving every minute, or every hour, but I believe that the danger is constant, because we never can know when it may come. I believe it is immediate, in the sense

that it is urgent and serious; and I believe that it is impending; from the fact that it is, as it were, hanging over the citizens of Missouri on the shores of the Mississippi all the time. I cannot help looking at the thing in this way. It is as if there were now located on the watershed of the Mississippi, since the opening of the drainage canal, a large additional city, a city notorious for its typhoid death rate, or for its typhoid epidemics,
249 I would say, and for its high death rate, too, from typhoid fever; and as if the placing of that city virtually upon the Mississippi watershed had introduced a new element into the life and welfare of the people on the river below. It is no trifling matter to take on a city of that size and add its sewage to an already sewage-polluted stream. The danger line may by that addition be reached soon—must, in the nature of things, be reached sooner—by those who use the water, and it is for that reason that I do regard the danger as impending, immediate and aggravated, as well as continuous."

(Sedgwick's testimony, Vol. 3, pp. 2217-18, 2225.)

Mr. Williams, at page 2467, stated in this connection as fol-

"In the history of water-borne diseases in America, while typhoid fever plays an important part, it comes far short of playing the entire part. Not only Asiatic cholera, but a large number of our common American diseases are undoubtedly transmitted through the water. Among those germs which have been found to have a considerable length of existence in water are the germs of diptheria, tetanus, and anthrax, as well as a considerable number of germs which are derived from the diseases of the lower animals. The germ of anthrax, for instance, is capable of producing very serious disease in both man and beast, and there have already occurred in the city of St. Louis cases

of anthrax, one of which has been traced, apparently, to the water supply, and the germ of anthrax is reported to have been found in the waters of the Illinois river. Anthrax is primarily a disease of the lower animals, and in France, where it has been especially prevalent in some provinces, it has been no uncommon thing for ten per cent of the sheep to be destroyed by it in a single year. A peculiarity of anthrax is the remarkable length of life of its spores, or seeds—which ever you may choose to call them—in water, they have been known to exist in it not only for months, but for years, and are practically indestructible. Should anthrax be prevalent among cattle, which are daily slaughtered in the Chicago stock yards, and from them be transmitted by the discharges from the nostrils, mouths or bowels of those cattle into the sewers of Chicago, there would be no question that the germs of anthrax might easily find a lodging in the people of Missouri with extremely fatal results. The germ of anthrax may not only be taken into the human system and produce disease by passing into the intestinal tract, but it is also susceptible of producing disease as a result of innoculation, so that a person bathing in water in which there were present germs of anthrax, if he had on his body any abrasions of the skin, would be particularly liable to receive an infection from anthrax, which might very probably end fatally. The germ of anthrax being practically indestructible under ordinary conditions, is frequently conveyed in hides and skins, and in the refuse from leather manufacturing establishments might easily get into the sewage of the city of Chicago as well as by way of the stock yards.

"The people of the State of Missouri, resident in the counties bordering upon the Mississippi river, are largely engaged in stock raising, and in times of drought, the Mississippi river is practically the only source of water for the stock so raised, and

it has come to my knowledge that in such times this water is carted for many miles from the shores of the Mississippi river to be used by both stock and the human inhabitants of the country adjacent. Should the sewage of Chicago become infected with germs of anthrax, and should those germs be transmitted, as they undoubedly would be, into the waters of the Mississippi, if the Chicago Drainage Canal continues to discharge the sewage of Chicago into the Des Plaines and Illinois rivers, at such times there would be great danger of the occurrence of an epidemic of anthrax, not only among the human inhabitants of the State of Missouri, but also among the lower animals using the water. Anthrax is recognized as one of the worst of water-borne disease with which we have to contend, for the reason that when once it becomes established in a community it may attack both man and beast, and its eradication can only be accomplished by the absolute destruction of the bodies of animals so infected. I may further add that the disease commonly known as glanders is also transmitted through water, and that it is not an uncommon disease among the stock of this country
251 at the present time, and the discharge of the sewage of Chicago, which is at any time liable to be contaminated by glanders, into the Illinois river, is another source of danger to the inhabitants of Missouri. In fact, as we look into the future and see the probable growth of Chicago, both in industries and in population, and the added probability of infection of its sewage due to the more general spread of infectious diseases, it seems to me that the danger impending over the citizens of Missouri as a result of the discharge of the sewage of Chicago through the drainage canal into the waters of the Illinois river is a most fearful menace to the health and welfare, not only of the citizens of Missouri, but of the citizens of other cities below the

mouth of the Illinois river, leaving entirely out of consideration the question of typhoid fever."

From all the facts presented in the case, taking into consideration the extent of typhoid fever deaths on the Illinois, Missouri and Mississippi river watersheds, exclusive of the city of Chicago, during the last four years, and comparing the same with the number of deaths occurring on the same watersheds, exclusive of Chicago, from 1895 to 1900, it is apparent that the opening of the Drainage Canal has been and is now a constant menace to the people of St. Louis and the State of Missouri using the water of the Mississippi for drinking purposes.

(Sedgwick's testimony, Vol. 3, pp. 2201-2230-2231.)

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27.

THE EFFECT OF THE SEWAGE OF CHICAGO UPON THE WATERS OF THE MISSISSIPPI AT THE CHAIN OF ROCKS IS SUCH AS TO PRODUCE AN INCREASE IN THE COST OF THE CONSTRUCTION AND OPERATION OF A SUITABLE FILTRATION PLANT TO PROTECT THE PEOPLE OF THE CITY OF ST. LOUIS AGAINST INFECTIOUS MATTER COMING FROM THE ABOVE NAMED CITY.

The constantly increasing amount of bacilli from the Sanitary District of Chicago, infected with disease producing organisms, coming through the Chicago Drainage Canal into the Mississippi river, will not render the water much less safe, generally speaking, than it was prior to the opening of the canal, but, by increasing the amount of infection and infectious material it creates an added responsibility as regards the treatment of the water of St. Louis so as to make it perfectly safe and wholesome for the people and citizens for consumption. Such treatment of the water under the conditions that exist now would involve a greater responsibility and financial expense. This increase in the cost would be shown by greater expense of supervising of the plant, and added cost of supplies used in connection with the operation of the works. It would also mean that such works be operated from time to time at lower rates of filtration than if the increase in infection were not present. The significance of this, that by reducing the rate of filtration, a larger plant will be required, and hence the more expensive an installation for the works to purify the same quantity of water than in the instance of water without the added infectious matter.

Looking into the future, and considering the various centers of population naturally tributary to the Mississippi river

at St. Louis, the Missouri and Illinois rivers, excluding the Chicago Sanitary District, it is certain that there will ultimately come a time when double filtration will be required to pro-
253 duce the results that single filtration can hardly be expected to produce now. When that time will come it is, of course, difficult to state specifically, as that will depend upon the rate of growth of the population of the cities situated upon the Illinois, Mississippi and Missouri rivers. But whatever the rate of growth may be, it is certain that the added infection will hasten the day when single filtration at St. Louis will prove unsatisfactory, and when it will be necessary to install a system of double filtration, which will necessarily involve an increased expense.

(Fuller's testimony, Vol. 3, pp. 2623-24.)

It is possible that the Illinois river might, under present conditions, become a stench to the nostrils of the people, in which case quadruple filtration is a possibility. And quadruple filtration may be necessary if the city of St. Louis persists in taking this water from the river. It is also possible that other types of purification may be required in connection with filtration, and the Chicago sewage will certainly very much hasten that day, whenever it may come.

(Fuller's testimony, Vol. 3, p. 2628.)

When water is being filtered for any purpose it ought to be done in the best possible way, having regard to the health of the people who drink it.

(See Fuller's testimony, Vol. 3, pp. 2632-37, inc.; Williams' testimony, Vol. 3, pp. 2402-3; Sedgwick's testimony, Vol. 3, p. 2382; Dr. Herbert E. Smith's testimony, Vol. 8, p. 7723.)

On this subject Dr. H. E. Smith testified thus:

"Q. Doctor, taking into consideration all the analytical data introduced in evidence by defendants and found in Streams Examination or otherwise, and taking into consideration the fact that Chicago sewage is discharged into the Illinois river by means of the Drainage Canal, and that the Sanitary District of Chicago has a population of more than 1,700,000, which is constantly and rapidly increasing, and taking into consideration the bacterial and chemical results shown from the
254 analysis introduced in evidence, taking into consideration the physical surroundings and conditions existing upon the Illinois river and the Mississippi river watershed above the Chain of Rocks, at all times and all seasons of the year, I will ask you to state whether or not, if a filtration plant should be established at St. Louis, the cost of its operation would be increased on account of the opening of the Drainage Canal and the passage of the sewage through the canal into the Illinois river, and taking into consideration the fact of this large amount of sewage continuously being discharged from the city of Chicago, state whether or not the operation of such a plant would require less cost if the deleterious and dangerous and infectious substances contained in the waters discharged from the canal into the river were eliminated from that river?"

"A. Taking into consideration the facts which you have called to my attention, I would state it as my opinion that the installation and operation of a filter plant at St. Louis would be more expensive by reason of the discharge of the sewage from Chicago into the Illinois river, and that if the deleterious agents in this sewage were removed that the cost of the installation and the maintenance of a filter plant at St. Louis would be lessened."

(Dr. H. E. Smith's testimony, Vol. 8, p. 7723.)

John W. Alvord testified thus:

"Q. Taking into consideration your knowledge of septic operation, and all that you know upon the subject of sanitary science and sanitary hydraulic engineering, and taking into consideration the physical condition of the Illinois river, the Drainage Canal and the Des Plaines river, and the chart or diagram introduced in evidence by Mr. Hering, and the diagram introduced in evidence by you in connection therewith, state whether or not in your opinion the presence of sewage from the Sanitary District of Chicago in the waters of the Mississippi river at the Chain of Rocks makes it more costly to provide suitable water for domestic purposes for the citizens of St. Louis?

"A. In my opinion it does make it more costly.

"Q. In what respect is the water supply of St. Louis
255 made more costly or difficult by virtue of the opening of the drainage canal?

"A. The design and construction of a purification plant dealing with a seriously polluted water, especially of one of known high typhoid pollution should be more complete and delicately adjusted to its work than when dealing only with water of rare infection and presenting less dangerous difficulties, such as turbidity and color.

"Q. What form should this added protection take?

"A. It should take the form either of double filtration or have complete sedimentation in more than one stage followed by most careful filtration.

"Q. State whether or not you know of any case where double filtration is being used or resorted to?

"A. It has been resorted to in several places in Germany, and has been recommended at Springfield, Massachusetts, by Messrs. George W. Fuller and Samuel M. Gray, and is now be-

ing introduced into the new filtration plant of Philadelphia by Mr. John W. Hill, in which case they are proposing to pass water of known typhoid pollution through what are called preliminary filters as a first stage, and then through slow sand filters as a second stage.

"Q. Would such methods be more expensive than single filtration?

"A. They would. It is my opinion that they would very greatly increase the cost of filtration, both in its first construction and in operation.

"Q. State whether or not single sand filtration as practiced in the United States is always a protection from the danger of typhoid infection?

"A. It is not.

"Q. Why is it not?

"A. Sand filtration of either type is practically able to remove pathogenic bacteria from domestic water supply, but we find that in practice filtration works are a most delicate mechanism, which have to be very carefully operated in order to produce at all times and under all conditions the results anticipated by their designers. In cases where the danger
256 of infection hovers over the filtration plant year in and year out it is obvious that the slightest relaxation may result in the most serious consequences.

"Q. State whether or not you know from your own observations and study of the cases in which single sand filtration or filter plants of either type have failed to protect the water supplies from typhoid infection?

"A. I do. There have come under my observation typhoid epidemics in water supplies protected by filtration in the following places:

Rock Island, Illinois.

Ashland, Wisconsin.
Berlin, Germany.
Lawrence, Massachusetts.
Lake Forest, Illinois.
Butler, Pennsylvania.
Waterloo, Iowa.
Beaver Falls, Pennsylvania, and
Augusta, Maine.

"Q. Mr. Alvord, are you a member of any engineering societies or associations?

"A. Yes, sir; I am a member of the American Association of Civil Engineers since 1893. I am a member and trustee of the Western Society of Civil Engineers. I am president of the Illinois Society of Civil Engineers and Surveyors. I am a member of the American Waterworks Association, and of the New England Waterworks Association. I am also a member of the American Public Health Association, and am serving this year upon its committee of water and sewage purification. I am a member of the American Association of Municipal Improvements of the American Academy of Social and Political Science and of the Engineer's Club of Chicago."

(Alvord's testimony, Vol. 8, pp. 7791-2.)

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28

COMPARISON OF TYPHOID FEVER DEATHS IN ST. LOUIS BEFORE AND AFTER THE OPENING OF THE CHICAGO DRAINAGE CANAL WITH OTHER CITIES.

In making a comparison of the typhoid deaths with like deaths in various cities of Europe and in the United States, Dr. Ravold testified as follows:

"The tables were taken from Hill's Work on Public Water Supply, and the number of deaths recorded are for each hundred thousand population.

ROTTERDAM.

"The water supply of this city is filtered, the water being taken from the Rivers Rhine and Maas. The number of deaths per hundred thousand population is as follows:

1890 6 deaths per hundred thousand population.
1891 4 deaths per hundred thousand population.
1892 6 deaths per hundred thousand population.
1893 5 deaths per hundred thousand population.
1894 5 deaths per hundred thousand population.
1895 2 deaths per hundred thousand population.
1896 12 deaths per hundred thousand population.

MUNICH, BAVARIA.

"Munich obtains its water supply from springs in the mountains, brought from Mangfall Valley, about 38 miles away.

1890 8 deaths per hundred thousand population.
1891 7 deaths per hundred thousand population.
1892 3 deaths per hundred thousand population.

1893 15 deaths per hundred thousand population.
1894 2 deaths per hundred thousand population.
1895 3 deaths per hundred thousand population.
1896 3 deaths per hundred thousand population.

258 BERLIN, GERMANY.

1890 9 deaths per hundred thousand population.
1891 10 deaths per hundred thousand population.
1892 8 deaths per hundred thousand population.
1893 9 deaths per hundred thousand population.
1894 4 deaths per hundred thousand population.
1895 5 deaths per hundred thousand population.
1896 5 deaths per hundred thousand population.

VIENNA.

"Vienna takes its water supply from springs in the Schneeberg mountains.

1890 9 deaths per hundred thousand population.
1891 6 deaths per hundred thousand population.
1892 8 deaths per hundred thousand population.
1893 7 deaths per hundred thousand population.
1894 5 deaths per hundred thousand population.
1895 6 deaths per hundred thousand population.
1896 5 deaths per hundred thousand population.

CHICAGO.

"Unfiltered Lake Michigan water.

1890 92 deaths per hundred thousand population.
1891 154 deaths per hundred thousand population.
1892 106 deaths per hundred thousand population.
1893 45 deaths per hundred thousand population.
1894 31 deaths per hundred thousand population.

1895 32 deaths per hundred thousand population.
1896 46 deaths per hundred thousand population.

PITTSBURG.

"Unfiltered river water.

1891 100 deaths per hundred thousand population.
1892 100 deaths per hundred thousand population.
1893 111 deaths per hundred thousand population.
259 1894 56 deaths per hundred thousand population.
1895 77 deaths per hundred thousand population.
1896 61 deaths per hundred thousand population.

LOUISVILLE.

"Unfiltered Ohio river water.

1890 88 deaths per hundred thousand population.
1891 81 deaths per hundred thousand population.
1892 72 deaths per hundred thousand population.
1893 84 deaths per hundred thousand population.
1894 72 deaths per hundred thousand population.
1895 77 deaths per hundred thousand population.
1896 45 deaths per hundred thousand population.

ST. LOUIS.

"Unfiltered Mississippi river water.

1890 94 deaths per hundred thousand population.
1891 30 deaths per hundred thousand population.
1892 37 deaths per hundred thousand population.
1893 103 deaths per hundred thousand population.
1894 31 deaths per hundred thousand population.
1895 19 deaths per hundred thousand population.

(Dr. Ravold's testimony, printed record, Volume 1, pp. 753-754-755.)

1896-1899, inclusive, 19.6 deaths per hundred thousand population.

1900-1903, inclusive, 34.7 deaths per hundred thousand population.

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29.

THE ACTUAL INJURY AND PERMANENT DAMAGE TO COMPLAINANT BY DEFENDANTS.

The full injury to complainant is apparent, beyond all doubt, as shown by the testimony in chief of Mr. Geo. W. Fuller and the rebuttal testimony of Mr. John W. Alvord, Dr. Herbert E. Smith and Prof. W. T. Sedgwick. Every word of it goes to the merits of the case with marked continuity and cannot well be disjointed. We therefore set forth portions of it in full:

MR. FULLER, testified in part as follows:

Q. Mr. Fuller, I will get you to state as a sanitary and water supply expert, what you consider to be the best index to the sanitary character of a public water supply?

A. As a general proposition it is my judgment that the best index to the sanitary character of a public water supply is the mortality record from water-borne diseases in the community using the water supply in question, and especially the mortality statistics of typhoid fever.

Q. Mr. Fuller, I will get you to state why the mortality statistics of typhoid fever are a better index, in your judgment, to the character of a water supply in a community than those of other water-borne diseases?

A. It is my experience that the typhoid fever mortality statistics are preferable to those of other water-borne diseases for a number of reasons, of which the principal ones are the wide-spread nature and distribution of typhoid fever, its abundance in those communities having supplied to them sewage polluted water; the well defined character of the disease, taking everything into consideration, and also the substantially large

percentage of deaths to those who have the cases; that is, the percentage of deaths to cases is larger than in some other instances. If Asiatic cholera should become established in this country I dare say that that might serve as an index to the sanitary character of water, substantially as well.

Q. Mr. Fuller, do you know how many people generally
261 speaking, sicken and die of typhoid fever each year in the United States?

A. Some years ago I gave that matter careful consideration. Generally speaking I would place the number of typhoid deaths on a very conservative basis, as at from 25 to 30 thousand annually in this country. As to the number of cases occurring in this country annually, of typhoid fever, I would place the figure at more than a quarter of a million.

Q. Mr. Fuller, what in your judgment was the sanitary character of the municipal water supply of St. Louis, after having passed through the settling basins as delivered to the consumers, during the years 1895 to 1899, inclusive, and upon what do you base your conclusions?

A. It is my judgment that the water supplied to the citizens of St. Louis by the municipal water department during the years 1895 to 1899, inclusive, was what might be called a good sanitary water. I base that judgment upon this fact: during the period mentioned, the typhoid fever mortality statistics showed as low a rate approximately speaking as in the case of quite a number of other American cities having a pure or very nearly pure water supply.

Q. Mr. Fuller, what treatment was given to the raw river water after its entrance into the intake tower at the chain of rocks and before its entrance into the service pipes of the consumers, in the city of St. Louis during the period from 1895 to

1899, inclusive, and how, if at all, did that treatment affect the sanitary character of the water?

A. The treatment at that time, that is from 1895 to 1899 inclusive, consisted of settling the water in the basins at the chain of rocks, which process I have already outlined in its general features. The result of this settling was to improve the water to a considerable degree as regards the elimination both of mud and of bacteria, including those of a pathogenic nature when such were present in the raw river water.

I will add another thing, and say that there was substantially no change in the period for sedimentation during the years in question.

Q. I will get you to state Mr. Fuller, whether or not the
262 term "pathogenic bacteria" is used by you to include water-borne bacteria that might convey infectious diseases such as cholera and typhoid?

A. Yes, sir.

Q. Mr. Fuller, what in your judgment was the sanitary character of the raw Mississippi river water as it entered the chain of rocks intake tower, St. Louis waterworks, during the years 1895 to 1899, inclusive?

A. It is my judgment that the raw Mississippi river water entering the intake tower during the period 1895 to 1899, inclusive, was a much less safe water from a sanitary standpoint than was the water after it had been treated in the settling basins, and delivered to the consumers. This was due of course to the elimination of bacteria of an injurious nature, by the process of sedimentation, and in which process the injurious bacteria subside—fall to the bottom of the basin and from time to time are removed from the basin and thus prevented from passing on with the water delivered to the consumers.

Q. How are the deposits made in the settling basins of the St. Louis waterworks removed, by the action of the water or by artificial means?

A. They are removed by artificial means, that is to say, once or more each year the basins are emptied, and the mud is flushed by the aid of water into channels, which conduct the mud to a sewer leading from the end of the basins to the river, and down below, a considerable distance below the intake tower.

Q. Mr. Fuller, referring to the sanitary character of the raw river water as it entered the chain of rocks intake tower during the years 1895 to 1899, inclusive, how would you classify that water as a city water supply?

A. I would classify it in its sanitary character as a suspicious water, meaning by that not distinctly a good water, but one in which there was a liability of danger from time to time to those who drink it in its raw condition.

Q. Mr. Fuller, I will get you to state if you know how the typhoid fever statistics in the city of St. Louis for the period since January, 1900, compare with those of the five pre-
263 ceding years, and if so, state the comparison?

A. During the period from 1895 to the end of the year 1902, the number of deaths from typhoid fever each year was as follows:

1895	106,
1896	107,
1897	125,
1898	95,
1899	130,
1900	168,
1901	197,
1902	222.

Averaging the number of deaths from typhoid fever during the five years, 1895 to 1899, inclusive, gives 112 deaths per annum from typhoid fever. The average annual deaths from typhoid fever during the three years beginning with January, 1900, is 196, showing an increase in round numbers in the number of deaths, of about 80 per cent.

Taking into consideration the differences in population, that is, the increase in population during that period, and expressing the typhoid fever deaths with reference to the number per 100,000 of population living, there has been an increase during the past three years on an average of about 60 per cent over the annual typhoid fever death rate per 100,000 population living for the five years 1895 to 1899, inclusive.

Comparing the number of deaths from typhoid fever during these eight years, with reference to the total number of deaths from all causes, occurring in the city of St. Louis, and obtaining the percentage mortality from typhoid fever, the percentage increase for the last three years on an average as compared with the average percentage of mortality from typhoid fever during the five preceding years, is 73 per cent.

I will further state that the average number of deaths from typhoid fever in St. Louis during the first five years under consideration was about 20.4 per 1,000,000 population living, and that this rate during the past three years, on an average, was about 32.3 on the same basis; that is, the average number
264 of deaths per annum per 100,000 population living.

Q. Mr. Fuller, I will get you to state if in your judgment the three methods of investigating and comparing typhoid fever statistics afford, when considered together, a proper and reasonable basis upon which to base conclusions with reference to typhoid fever statistics of the city?

A. In my judgment that is true, for the reason that each throws light upon the matter, but the data regarding the two last methods of comparison taken together, are the fairest and best way.

Q. Now, Mr. Fuller, I will get you to state, speaking broadly, what in round numbers, considering all of these methods, and all of the facts, you consider the increase of typhoid in St. Louis to be, in the periods mentioned in the former question?

A. I should say in round numbers there has been an increase during the second period under consideration of about sixty to seventy per cent above the average rate in the earlier period mentioned.

Q. Mr. Fuller, I will ask you if you know how the typhoid fever statistics of the city of St. Louis for the period covered by the first five months of each year since 1895 to 1899, inclusive, compare with the first five months of the three years since January, 1900; if so, state what that comparison is?

A. The number of deaths from typhoid fever in St. Louis during the first five months of the years 1895 to 1899, show sums or amounts very much less than during the first five months of each of the years following 1899; that is, 1900, 1901, 1902 and 1903. This is particularly true of the present year, 1903.

Q. Do you know, Mr. Fuller, the mortality from typhoid fever for the five months of the year 1903 by months?

A. In January, 1903, there were 15 deaths,
In February, 1903, 15 deaths,
In March, 20 deaths,
In April, 17 deaths, and
In May up to date, 18 deaths.

Q. These statistics are for the city of St. Louis are they,
265 Mr. Fuller?

A. City of St. Louis.

Q. Mr. Fuller, are you enabled by any methods of judgment of typhoid statistics, that you have mentioned, and from your general knowledge to say whether or not these figures for the year 1903 indicate an increase or a decrease of the typhoid fever in this city?

A. They clearly indicate an increase in typhoid fever in this city.

Q. Mr. Fuller, I will get you to state if you know whether or not from the facts in your possession and the statistics that you have stated and are aware of, if typhoid fever shows any signs of abating in this city?

A. The record of the number of deaths from typhoid fever in the city of St. Louis by months shows a continuance of these comparatively high figures to an unusual degree, showing that for this season of the year there is an unusual prevalence of this disease in this city.

Q. Mr. Fuller, I will get you to state to what cause you ascribe the increased mortality from typhoid fever in the city of St. Louis since January, 1900, and why?

A. I ascribe it to an increased amount of infection in the public water supply, and predicate this opinion upon the practically uniform distribution of the homes or residences in which the typhoid deaths have occurred in the city of St. Louis, and the further fact that a careful examination of the several other possible sources of typhoid fever shows that no substantial portion of this increase may be explained in that way.

Q. Mr. Fuller, what in your judgment has been the sanitary character of the public water supply of St. Louis after passing through the settling basins as delivered to the water consumers since January, 1900?

A. I consider that the sanitary character of the public water supply delivered to the consumers in the city of St. Louis has been less safe than it was formerly.

Q. Mr. Fuller, I will get you to state if, in your judgment, the water supply of St. Louis, as delivered to the consumers, after passing through the settling basins since January,
266 1900, can any longer be classed as a good water?

A. It is my judgment that it cannot be classed as a good water.

Q. Mr. Fuller, what has been the treatment of the raw river water after it leaves the chain of rocks, intake tower, and prior to its reaching the consumers in the city of St. Louis during the period since January, 1900, as compared with the five preceding years?

A. The treatment has been essentially the same.

Q. Mr. Fuller, what in your judgment, has been the sanitary character of the raw Mississippi river water as it enters the chain of rocks intake tower, since January, 1900, and how does it compare with that of the five preceding years?

A. I consider that the sanitary character of the raw Mississippi river water entering the intake tower of the St. Louis waterworks since January, 1900, has been distinctly and decidedly less safe than during the five preceding years.

Q. Mr. Fuller, generally speaking, what is the principal source of dangerous impurities in public water supplies in their raw condition?

A. Sewage pollution.

Q. Mr. Fuller, I will ask you if you are familiar with the relative amounts of typhoid fever prevailing on the area naturally tributary to the Mississippi river above the chain of rocks, for the five years preceding, and the three years since January, 1900, and what do you say as to the relation between the conditions in the sanitary character of the raw Mississippi river water at the chain of rocks intake tower and the prevalence of typhoid fever within the natural limits of the Mississippi water-

shed above St. Louis; that is, exclusive of the Chicago Sanitary District?

A. I am generally familiar with the typhoid fever statistics in the larger centers of population upon the Mississippi watershed, above the chain of rocks, intake tower of the St. Louis waterworks, and excluding the Chicago sanitary district during the periods mentioned in the question. During these periods there have been at quite a number of points some variation in the amount of typhoid fever prevailing in different
267 years. Taking the typhoid fever statistics upon this watershed area as stated, as a whole, but excluding the Sanitary District of Chicago, based upon the average number of deaths from typhoid fever per year, it is my judgment, viewing the matter as a general proposition, that there has not occurred on the natural area of the Mississippi watershed above St. Louis any increase in the number of deaths sufficient to explain to any material degree the less safe condition of the Mississippi river water as taken from the intake tower of the St. Louis waterworks, during the last period, as compared with the period of 1895 to 1899.

Q. I will get you to state, Mr. Fuller, if you know of any cause that renders the water, if it is, less safe—that renders it so at the intake, at the chain of rocks now, and within the last three years, than prior to January, 1900?

A. In my judgment, it is the Chicago Drainage Canal discharging sewage and drainage containing filth and infection, from the city of Chicago, which makes the water in its raw condition at the intake tower, chain of rocks, St. Louis waterworks, less safe than it was preceding January, 1900.

Q. Mr. Fuller, I will get you to state if you know, how many deaths from typhoid fever have occurred since January, 1900, in the city of Chicago, and what has been the disposition

of the infectious discharges of the persons sick with this disease?

A. There have been about 1647 deaths from typhoid fever in Chicago since January, 1900, and the infectious discharges from the persons sick and dying of typhoid fever have to a very large degree been disposed of by their passage through the sewers to the Chicago river and the Chicago drainage canal.

Q. Mr. Fuller, I will get you to state whether or not you have made an estimate of the approximate number of persons sewering into the Mississippi river and its tributaries, exclusive of the Sanitary District of Chicago. If so, what figures have you obtained and upon what basis as to the separating of the rural from the sewage contributing population?

A. I have looked into this matter and in round numbers place the figure for those people who sewer directly into the Mississippi and its branches and tributaries above the St. Louis waterworks and exclusive of the Sanitary District, at
268 about 2,700,000. This figure is based upon a separation, on an average of the sewage contributing population from the rural population by taking towns of 4,000 and over as representing those who have sewerage systems and contribute sewage directly to the water courses. Some of the towns of more than 4,000 population are undoubtedly not provided fully with sewerage facilities. On the other hand, there are quite a number of towns of less than 4,000 population which in a limited measure do have waterworks, and do have some sewerage. Looking at this question as a practical proposition, it is my judgment that the amount of the sewage-contributing population in towns of less than 4,000 inhabitants no more than off-sets in the aggregate the amount of population in the cities larger than 4,000 inhabitants which do not have sewers. It is a fact well known among practical waterworks and sewerage people that the num-

ber of miles of water mains in a town ordinarily exceeds to a considerable degree the number of miles of sewer lines. In making this statement as to the number of people in the aggregate sewering into the Mississippi river above the chain of rocks intake, I include of course, the Missourr river and the Illinois river, exclusive of the Chicago Sanitary District, as well as the upper Mississippi.

Q. Mr. Fuller, why did you draw a line at the towns of 4,000 inhabitants for the separation of population contributing pollution directly, from those which contribute indirectly?

A. Well, that matter I took up pretty thoroughly in the last answer I gave, and will state that the basis as described in my last answer is the result of my experience and I think that on the whole it is a reasonable and fair method due to its compensation of the two factors; first, the amount of population in the cities above 4,000 which do not sewer directly into the river and secondly, the population of some towns of less than 4,000 which do contribute sewage directly to the water courses.

Q. Mr. Fuller, what would you estimate to be the percentage of increase in population sewering into the Mississippi river valley above St. Louis, due to the Chicago Drainage Canal bringing sewage of Chicago into the Mississippi river watershed?

A. In round numbers I estimate an increase of 60 per cent.

Q. Mr. Fuller, please state, if you know, what course the
269 diluted sewage follows, after the contents of the drainage canal, containing the filth and infection of the Chicago Sanitary district, after it flows from the Bear Trap Dam at Lockport and into the Des Plaines river?

A. The contents of the Chicago drainage canal after entering the Des Plaines river below the Bear Trap Dam at Lockport, flows along the course of the Des Plaines river, which river joins the Kankakee, and the two form the Illinois river. The

contents of the drainage canal thence flow throughout the entire length of the Illinois river and enter the Mississippi at Grafton, which is distant about 291 miles from Lockport.

Q. Mr. Fuller, how long a time do you estimate is required for the Chicago sewage to flow this distance of 291 miles from Lockport to Grafton?

A. I place the figures ordinarily at from ten to twenty-five days. That range of course depends on the velocity of flow of water in the river.

Q. What would you estimate the average to be in time to make the flow from Lockport to Grafton?

A. It is my opinion that the average time required for the flow from Lockport to Grafton is about 15 to 18 days. In this connection I would further state that there are portions of the stream, mainly the upper portions, which flow more rapidly than the lower portions, and some water presumably reaches Grafton quicker than indicated by the average above mentioned.

Q. Mr. Fuller, what, in your judgment, is the period of time which typhoid fever germs may and do continue to live in sewage polluted waters such as are found in streams, reservoirs and the like?

A. I consider that they may and do continue to live for weeks and months under those conditions.

Q. Mr. Fuller, what do you say as to the longevity of the germs of Asiatic cholera under the conditions mentioned in your last question?

A. The life history of the germs of Asiatic cholera under the conditions mentioned is less accurately known than in the case of the typhoid fever germs. Generally speaking, however, it is my opinion that there is not any very great difference
270 in the life history of the germs of the two diseases, under the conditions stated in the question.

Q. Mr. Fuller, in your judgment, what is the influence or effect upon the sewage discharged into the Des Plaines river at Lockport, of the dilution which, under existing conditions, takes place in the Illinois river, viewing this question from the standpoint of a hygienic or sanitary character of the Illinois river water, as it enters the Mississippi river at Grafton?

A. The dilution of the Chicago sewage, as it flows from Lockport to Grafton, by the waters of the Illinois river and tributaries, is a very variable proposition. At times the dilution of the contents of the Chicago Drainage Canal by the flow of the Illinois river and its tributaries, is very considerable. At other times the volume of flow of the Chicago Drainage Canal exceeds the flow of the Illinois river, this being true particularly in its upper reaches. There consequently results at times a dilution of the Chicago sewage by the waters of the Illinois river, and other times a dilution of the Illinois river by the contents of the Chicago Drainage Canal. Dilution at best does not destroy disease germs of infectious matter. Its effect is to minimize the danger to those who may drink of the water so diluted. One effect of the dilution existing in the Illinois river at low stages is to bring to Grafton more quickly than would otherwise be the case, injurious matter entering the Illinois river at points along the route of its flow, and also entering the Illinois river from cities and towns located upon the tributaries to that river.

Q. Mr. Fuller, in your judgment, what is the significance of the ponds and of the dams and of the slack water stretches which are found on the Illinois river, regarding the hygienic or sanitary character of the diluted Chicago sewage flowing from Lockport to Grafton?

A. The most significant feature of these so-called lakes, dams and slack water stretches is the low velocity of flow of the water, at times of low stages of the Illinois river. There

are a good many days in the course of a year when these velocities at the places above referred to are so low that deposition takes place to a considerable degree, of the bacteria and other matters supended in the water, and which to a large de-
271 gree are derived from the contents of the Chicago Drainage Canal. The deposition of the bacteria, including those of infectious diseases like typhoid fever, does not mean their permanent elimination and removal from the flowing water. The reason of this is that as they reach the bottom and lie upon the bed of the stream they are disturbed from time to time, due to changes in velocity of stream flow, such as caused by moderate rains, or by the passage of boats or the action of the wind and the like. The resulting disturbances cause the bacteria to leave the bed of the stream in which they may rest for some time, bringing about a return of those bacteria to the flowing water. In this way the germs of disease may pass from the Chicago drainage canal at Lockport to the mouth of the Illinois river at Grafton.

Q. Mr. Fuller, is it or is it not your opinion that typhoid fever germs disappearing from the flowing stream and becoming deposited in the bed, are able to live there for weeks or months?

A. I think that they are able to live for weeks and months.

Q. Mr. Fuller, I will get you to state if in your judgment it is possible, that the water of the Illinois river as it flows into the Mississippi may sometimes be richer in typhoid fever germs derived from the sanitary district of Chicago and coming through the drainage canal than was that portion of the water drawn from the drainage canal when it flowed over the Bear Trap Dam?

A. In my judgment such a condition of affairs at times is not only possible but probable.

Q. Why?

A. Such a condition of affairs may arise and at times probably does arise through the disturbances of the sediment lying upon the bed of the stream in places, which sediment may and undoubtedly at times does contain relatively large numbers of typhoid fever germs. As these typhoid fever germs are returned to the flowing stream from their position in the bed of the river there is effected an accumulated result, whereby at times at least the waters of the Illinois river flowing to Grafton, may discharge the concentrated essence of the infection of Chicago sew-
272 age, by taking in the manner above described, portions of the infection coming from many days' flow of the drainage canal into the Illinois river.

Q. Mr. Fuller, I will get you to state if you know of any cases excepting storage reservoirs connected with public water supplies, in which sedimentation is employed for the purification of sewage or sewage polluted water without any provision having been made for the removal of the sedimentated materials so that these shall not find their way back to the flowing stream?

A. I know of no such instance, and it is obvious that if means are not provided for the removal of sedimented materials from time to time under proper conditions so that they will not re-enter the water as it leaves those basins, then the object and purpose of the settling basins largely fails.

Q. Mr. Fuller, do you or do you not consider that all existing circumstances and conditions from Lockport to Grafton, taken separately or together, are sufficient to prevent at all times the pollution and infection coming from the Chicago Sanitary District and entering the Mississippi valley at Lockport, from reaching the Mississippi river at Grafton?

A. I believe that those conditions are not sufficient to prevent at all times infected materials coming through the Chi-

cago drainage canal and entering the Mississippi valley at Lockport, from reaching the Mississipi river at Grafton.

Q. Mr. Fuller, do you know how far it is from Grafton to the Chain of Rocks, water tower?

A. About 29 miles.

Q. Do you know how long a time is required for the Mississippi river to flow from Grafton to the chain of rocks?

A. It is a fraction of one day.

Q. That is in the ordinary stage of water?

A. Yes, sir.

Q. Mr. Fuller, is it or is it not possible, in your judgment, for the Illinois river water entering at Grafton the Mississippi river, which in turn is joined with the Missouri river six miles above the Chain of Rocks, to flow past the Chain of Rocks without some of the Illinois river water ordinarily entering the

273 intake tower of the St. Louis waterworks?

A. I don't believe that it is possible for the Illinois river water to flow by the Chain of Rocks without some of it ordinarily entering the Chain of Rocks intake tower of the St. Louis waterworks.

Q. Mr. Fuller, in view of all the facts and conditions as you know them, do you or do you not consider that the sewage of the Chicago Sanitary District pollutes and infects the water of the Mississippi river along the Missouri shore, and especially at the Chain of Rocks intake tower of the St. Louis waterworks to such an extent that it makes the Mississippi river water less safe for drinking and domestic purposes than it was before the opening of the drainage canal?

A. It is my judgment that it does.

Q. Mr. Fuller, assuming that during the three years before and the three years after the opening of the Chicago drainage canal, the total number of typhoid fever deaths so far as

can be learned, was about the same on the watershed of the Mississippi river above the intake tower of the St. Louis waterworks at the Chain of Rocks, exclusive of the Sanitary District of Chicago, and that here were 337, 509, and 801 typhoid deaths in 1900, 1901 and 1902, respectively, making a total of 1,647 typhoid deaths for these three years in the city of Chicago since the opening of said canal; state whether or not the said deaths in Chicago have, in your judgment, had any influence on the typhoid fever mortality of the city of St. Louis, and if so, what?

A. It is my judgment that under the conditions assumed in the question, the typhoid infection coming from Chicago and passing through the drainage canal by way of the Des Plaines and the Illinois rivers to the Mississippi river and to the intake tower at the Chain of Rocks, of the St. Louis waterworks, did have an influence upon the typhoid fever death rate in the city of St. Louis, and that it is the cause of the principal portion of the increase during the past three years.

Q. Mr. Fuller, assuming that the population of the sanitary district of Chicago grows larger, and that the amount of Lake Michigan water and of the sewage sent down the
274 drainage canal and on into the Mississippi river under conditions corresponding in method of procedure to those which prevail today on the Des Plaines and Illinois rivers, thereby increasing the amount of infected sewage entering the Mississippi watershed, what effect could such future growth of population in Chicago, and such future increase in added pollution to the Mississippi river waters, reasonably be expected to have upon the sanitary quality of the water of the Mississippi river in its raw condition, arriving on the shores of the State of Missouri below the mouth of the Illinois river and especially at the intake of the St. Louis waterworks at the Chain of Rocks?

A. Under the conditions assumed in the question it is my

opinion that the water in the Mississippi river along the Missouri shore, especially at the Chain of Rocks, intake tower St. Louis waterworks, in its raw condition, would be rendered less safe than at the present time, due to the increased amount of infection entering the Mississippi watershed from Chicago and to the shorter interval of time required for the passage of that sewage from Chicago to the points considered, on the Missouri shore of the Mississippi river.

Q. Mr. Fuller, what effect, if any, in your judgment would the increasing amount of sewage from the sanitary district, coming through the drainage canal into the Illinois river in future, caused by the growth of population in the sanitary district of Chicago, have upon the Illinois river and the Mississippi river at low water stages?

A. It would make it a much less safe water generally speaking, than at the present time, and it is quite possible that looking far enough into the future, that this amount of pollution would become sufficient to exceed the oxygen and to make it in many ways resemble an open sewer; that is to say, it will be a stagnant pool, resembling sewage rather than a live, natural water containing atmospheric oxygen.

Q. Mr. Fuller, I will get you to state if in your judgment the increased sewage coming into the Illinois river by way of the drainage canal and thence into the Mississippi, now, and in the future, would add any difficulties, or increase any cause to the problem of filtering or otherwise purifying the water
275 of, and furnishing with safe water, the city of St. Louis?

A. In my judgment the increased amount of infection coming into the Mississippi river from the city of Chicago's sewage at the present time makes an added responsibility as regards the treatment of that water, to make it perfectly safe and wholesome as supplied to the citizens of St. Louis. Such treatment of

the water would involve, I think, at the present time, more responsibility, and in a financial way, it would be shown by the greater expense of supervision of a filtration plant, and the added cost of supplies used in connection with the operation of filtration works, especially at times of low water. It would also mean that such filtration works, if adopted, would be operated from time to time, if not regularly, at lower rates of filtration than if this increased infection were absent. The significance of this is that by reducing the rate of filtration, that a larger plant would be required, and hence a more expensive installation for filtration works, to purify the same quantity of water than in the instance of water without this added infectious matter.

Looking some distance into the future and considering the various centers of population naturally tributary to the Mississippi river at St. Louis, the Missouri and Illinois rivers, but excluding the Chicago Sanitary District, it is certain that there will ultimately come a time when single filtration can hardly be expected to produce a satisfactory quality of water with its source at the Chain of Rocks, intake tower. When that time will come it is difficult to state specifically, as it will depend upon the rate of growth of population in the communities situated upon the watershed of the Mississippi, Illinois and Missouri rivers, exclusive of the Sanitary District of Chicago.

Whatever the rate of growth may be in the communities situated upon the watershed of the Mississippi river above St. Louis, independent of the city of Chicago, it is certain that the added infection of the Mississippi water at the St. Louis intake due to the Chicago sewage, will hasten the day when single filtration at St. Louis will prove unsatisfactory, and when it will be necessary to give attention either to double filtration or

to other methods, involving increased expense and in-
276 creased responsibility." (Fuller's testimony, Vol. 3, pp. 2607 to 2624.)

DR. HERBERT E. SMITH: In rebuttal, Dr. Herbert E. Smith, on the chemical condition of the waters in question, said in part, as follows:

"Now, Doctor, I show you tables 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, introduced and read in evidence by Professor Kinnicutt, these tables showing the mean of Professor Jordan's and Palmer's result, May to December, 1899, in the Illinois river, Joliet, north of Jackson street; Ottawa, LaSalle, Henry, Averyville, Pekin, Havana, Beardstown, Kampsville and Grafton. I will ask you to state what conclusions you draw from these tables, and what these tables of mean results show with reference to the condition of the stream at these points, as to its average pollution at all times of the year?

A. These results show the average composition of the samples of water at the times and places at which they were collected. The several samples show that in the upper portion of the water way there was a very high chemical and bacterial pollution; that there was a gradual diminution in the amounts of the various chemical constituents in the progress down the river, and that there were certain places where there was an increase in these constituents; the figures for the samples taken at Grafton show that there was in those samples a very considerable evidence of sewage contamination still remaining. There was some variation in this diagram, also in bacteria, the number at the Grafton station being somewhat higher than at the Kampsville station, for instance.

The tables fail to show the true conditions of the river at these several stations at all times because a sample taken from a running stream, from time to time, can not of course show the

composition of the river at that place at other times, and further, there is no evidence in these tables that the samples taken at the time they were taken were proportional to the flow in the river, and obviously they would represent a different proportion of the constituents in the river at times of flood from what they would at the time of low water, the samples being of the
277 same size.

Q. I show you tables 57 to 64, inclusive, Doctor, introduced in evidence by Professor Kinnicutt, and based upon the mean of Jordan and Palmer's results, from January to June, 1900, and the following points in the Illinois river: Table 53, Joliet; table 54, Morris; table 55, Ottawa; table 56, LaSalle; table 57, Henry; table 58, Averyville; table 59, Wesley City; table 60, Pekin; table 61, Havana; table 62, Beardstown; table 63, Kampsville, and table 64 at Grafton, and ask you to examine these tables and state whether or not from the mean results shown by them positive conclusions can be drawn as to the sanitary condition of the water in the river at those points at all times in the year?

A. In my opinion these tables do not show the condition of the water in the river at the several points at all times of the year for the reason that the samples were taken occasionally and not continuously; that they did not as far as the tables show, take into consideration the flow at the time the samples were taken, and that in general an average of this sort can not show the condition of the stream at other times than those at which the samples were taken.

Q. Doctor, I will show you tables 1 to 12, inclusive, introduced in evidence by Professor Kinnicutt, as giving the mean of Detors Long and Palmer's results for May, June, July and August, 1899, and 13 to 24, inclusive, the mean of Doctors Long

and Palmer's results for May, June, July and August, 1900, and will ask you to state what, in your opinion, is the value of these tables as to their showing the sanitary condition of the water in the Illinois river at all times of the year?

A. In my opinion these tables fail to show the condition of the water in the river at all times and seasons for similar reasons stated in my answer to your last question.

Q. Doctor, have you examined the individual results upon which these averages were based?

A. I have.

Q. State whether or not you have noticed any individual samples, the determination of which deviate markedly from the average in the evidence of sewage pollution?

A. In my examination of the individual results upon
278 which these tables of averages are based, I have noted many results which deviate widely from the average.

As an illustration, on table 101 in the Streams of Examination, which relates to the analysis of the Illinois river at Grafton during 1899, I find that on November 8th, the samples showed a chlorine of 4 parts per million; on May 31st of 3.7 parts per million, while the average given in Professor Kinnicutt's table of the results obtained at this point is 18.4 parts per million.

I would say that on that particular table there were 17 samples, more than half, therefore, that were above the average in chlorine, and there were 16 that were below the average.

With regard to the free ammonia, I find that on December 6th there was present 1.12 parts per million, and on June 21st, .04 parts per million, while the average of all the determinations at that point gave 0.23. There were 12 samples above the average and 21 samples below the average.

In the same tables, the figures for suspended matter, or

suspended residue referred to in another place as suspended solids, was, on May 31st, 873.8 parts per million, and on October 11th was 1 part per million, while the average of all the determinations is given as 82.4.

These indicate some of the ranges which I have noted, and similar discrepancies are found in the other tables.

Q. Doctor, state whether or not and in what way, if any, true conditions fail to be displayed from the tables of averages such as these about which we have been testifying?

A. The general average does no show a true condition because the general average can only relate to the conditions at the times and places when and where the samples were taken.

In a stream of running water, which varies in volume, it is very important that the samples should be taken in such volume as will indicate the relative flow at the time the samples are taken.

For another reason a sewage contaminated stream varies greatly from time to time in its content of impurity, depending largely upon the irregularities in the discharge of the sewage, at one time the sewage being of a certain character and at another time differing widely from it, either because of the
279 sort of discharge of materials from factories or manufacturing establishments or something of that sort, or from the variations which are found in the flow of sewage in the matter from houses at or during different hours of the day. Moreover, there is a very marked difference in the flow of streams, due to the variable rainfall at different seasons and times. This has the effect not only of increasing the volume of the flow, diluting it at one time, the constituents over the conditions which prevail at another time, but the larger flow tends to bring down the stream accumulated materials and form movable deposits, both upon the watershed and in the stream

itself. For these various reasons an average result can not show the condition of the stream at all times.

Q. Doctor, in the present developed state of sanitary science, state whether or not a table of averages, such as were introduced by Professor Kinnicutt, are considered by the scientists as sufficient to enable one to make a competent determination of the sanitary condition of water in a running stream?

A. In my opinion the tables of averages which are referred to as having been introduced by Professor Kinnicutt do not form a competent basis in the present condition of sanitary science to permit a definite opinion as to the sanitary condition of the stream to which they relate.

Q. Upon what do you base your last answer?

A. I base my answer first upon the reasons already assigned why a general average can not be taken as representing the general character of the stream to which they relate at all times.

And further, I base my opinion upon my belief that chemical analyses do not and can not show all the evidences of dangerous pollution which may exist in a stream. The chemical analysis is addressed to the deduction and determination of certain elements which are useful in determining the presence or not of sewage in a stream, but in the present state of the science it is impossible to decide whether certain results are or are not evidence of sewage contamination; and further, that there are certain ingredients which may be present in a stream coming from sewage and which are of material importance
which are not revealed at all by the chemical analysis. In
280 my opinion, therefore, the chemical analysis alone is not a
sufficient basis to decide whether a sewage polluted stream contains the dangerous elements of sewage.

Further, I base my opinion upon my belief that in the present state of sanitary science the bacteriological analysis does not reveal in all cases the presences of those constituents of sewage which are dangerous.

And, further, I would state that in the present condition of sanitary science, neither the chemical nor the bacteriological analysis alone, nor both together, can be absolutely relied upon to show the presence in a stream of those substances which may come from sewage and do come from sewage and which are dangerous.

Q. Doctor, have you examined the book, known as Streams Examination, all the tables from which were introduced in evidence in this case, have you?

A. I have.

Q. In giving your answer to the last question have you considered the tables contained in this book, known as Streams Examination, and what you have learned from it?

A. In answering your questions relating to the analysis I have taken into consideration the information which I obtained by consideration of the tables in the book known as Streams Examination.

Q. From your examination of all the tables contained in this book known as Streams Examination, and which said tables have been introduced in evidence, and from the tables introduced in evidence by Professor Kinnicutt, state whether or not you are able to say that all the harmful elements and disease producing bacteria discharged into the canal at Chicago have become eliminated from the Illinois river by the time that it reaches Grafton?

A. From my examination of the results given in the tables in the book, Streams Examination, and of the tables of averages based thereon, I would say that I am unable to state that

they show that all injurious ingredients have been eliminated from the sewage.

Q. Are you acquainted with the extent of the popula-
281 tion residing upon the watershed of the Illinois river, the rural and the urban population?

A. I have seen the figures, yes, sir.

Q. Have you acquainted yourself, Doctor, with the relative amount of sewage that is immediately discharged into the Illinois river for the various periods mentioned, upon the Des Plaines and upon the banks of its tributaries, exclusive of the Sanitary Districts of Chicago.

A. I have examined the figures showing the amount of sewage discharged into the Illinois river at various points upon its course.

Q. Doctor, have you made yourself acquainted with the velocity flow of the Illinois river from Chicago to the Mississippi?

A. I have examined figures showing the flow of the Illinois river at the points mentioned.

Q. The figures that you examined in reference to that were those determined by Professor Van Ornum and Isham Randolph, are they not?

A. I understood that they were the figures introduced by the gentlemen named.

Q. Taking into consideration, Doctor, the extent of the urban population residing upon the watershed of the Illinois river, exclusive of the city of Chicago, and taking into consideration the usual volume of water passing down that river, together with the added volume of 250,000 cubic feet per minute, from Chicago, state whether or not in your opinion the chemical and bacterial results shown upon the tables contained in Streams Examination and the results upon the tables introduced in evi-

dence by Professor Kinnicutt show the sanitary chemical and bacterial condition of the water in the Illinois river to be higher or lower from a sanitary standpoint than ordinarily exists in rivers of this kind having similar population and flowing similar volumes of water?

A. Taking into consideration the urban population upon the several watersheds tributary to the Illinois river, exclusive of that of the Chicago Sanitary District, I will state it is my
282 opinion that the results shown in the tables in the examination of streams and in the tables of averages based upon them, show that at the times when these samples were taken there was more evidence of sewage than I should expect in a river of this size and population.

Q. State whether or not in your opinion, Doctor, the chemical and bacterial data found in the tables contained in Streams Examination, and the tables introduced in evidence by Professor Kinnicutt, show more or less any such bacterial and chemical constituents which are usually considered as evidence of sewage than which you would expect in event the sewage from the sanitary districts of Chicago was not discharged into that river, the same volume of water flowing down the river in each event?

A. In my opinion the tables referred to do show that there was at the time when the samples were taken more evidence of sewage contamination than I should expect to find from the urban population on the watersheds tributary to the Illinois river, exclusive of the Chicago Sanitary District."

(H. E. Smith's testimony, Vol 8. pp. 7685-7694.)

Of the dams on the Illinois river and their effect on the water, Dr. Smith said:

"Q. Assume, professor, that a larger portion of the sewage of Chicago passed through the old Illinois and Michigan Canal in a more concentrated condition than it does through the drain-

age canal; assuming further that during the greater part of the year, under such conditions the water in the Illinois river, practically from Grafton to Henry, was covered with a green scum as though in a quiescent condition, and as described by some of the fishermen on the river, who testified for respondent, stood in a stagnant condition with no perceivable current, such that when a skiff would be rowed across it, it would separate the green scum and leave the line of separation distinct and visible for a great distance behind; that if a chunk should be thrown in the river it was as liable to float up stream as down stream, depending altogether upon the direction of the wind; that the five dams practically retarded the progress of the water down the stream;

that in order to protect navigation it was necessary for them
283 to erect banks on top of the dam so as to increase the height

of the water above the dam; assuming further than since the opening of the canal that there has been a continuous current at all times of the year, both above, below and over the respective dams. State whether or not upon these assumptions the facilities for removal of the pathogenic bacteria and harmful ingredients of the water coming from the sewage of Chicago were not better prior to the opening of the drainage canal than subsequent to that time, and also is it not a fact that such facilities for removal are not and can not be displayed by the tables of averages and by the tables themselves contained in Streams Examinations and introduced by Professor Kinnicutt and which you have examined, the volume of water that passed through the Illinois and ranging from 19,000 to 49,000 cubic feet per minute, and the volume of water passing through the drainage canal since its opening ranging from 200,000 to 250,000 cubic feet per minute?

"A. In answering your question I have taken into consideration the assumptions and statements made and would state it as my opinion that the conditions assumed and stated to be

present in the river prior to the opening of the drainage canal were such as would afford greater facilities for the removal of pathogenic organisms which exist since the opening of that canal.

"A. And, further, I would state as my opinion that the data furnished by the tables in the book of Streams Examination, and the tables based thereon, do not furnish data for determining the extent to which these pathogenic organisms have been removed." (H. S. Smith, Vol. 8, pp. 7695-7696.)

HARMFUL SUBSTANCES PASS FROM CHICAGO TO ST. LOUIS.

"Q. Speaking as an expert in the interpretation of sanitary water analysis, bacterial analysis and all other means of determining the sanitary condition of a running stream, I will ask you to state your opinion concerning the purification of the sewage of Chicago at the time it passes out of the drainage
284 canal.

"A. Basing my opinion upon the results of the chemical and bacteriological analysis which have been furnished, and the tables referred to, and upon other data within my knowledge bearing upon the subject, I would state it as my opinion that the sewage is not purified from the harmful agents at the time it is discharged from the drainage canal.

"Q. Assuming that the water passes from the city of Chicago through the canal into the Des Plaines river, and down the Illinois to the Mississippi, past the Chain of Rocks at St. Louis, within from ten to twenty days, state your opinion as an expert on water supply for cities and towns as to whether or not the waters of the Mississippi river at the Chain of Rocks are less available for drinking purposes and more liable to contain water borne diseases such as typhoid now than it did before the

sewage of the Sanitary District of Chicago was borne into the drainage canal and through it to the Illinois river?

"A. I will state it as my opinion based upon the facts which you have stated, that the water at the Chain of Rocks is less available for sanitary use than it was before the opening of the sanitary canal, and that there is a very much greater liability of the infection with typhoid bacilli of persons drawing water from that point in the river.

"Q. Doctor, Professor Kinnicutt, in his direct examination by counsel for respondents, was asked this question, and I desire to ask it of you: If an increased volume of water in the Illinois river, by the addition of the water of the drainage canal at the rate of 250,000 cubic feet per minute would make an increased speed in the current of the Illinois river, would that increase in said current have any effect in increasing or diminishing the liability to typhoid and other water borne diseases on the part of the inhabitants of the State of Missouri using the water of the Mississippi river for drinking purposes below the mouth of the Illinois?

"A. In my opinion an increase in the flow of the Illinois river as assumed would very largely increase the liability of the infection of persons drawing a water supply consisting in whole or part of water from the Illinois river." H. E. Smith, Vol. 8, pp. 7697-8.)

INFORMATION NECESSARY TO ENABLE SANITARIANS TO DETERMINE CONDITION OF WATER.

285 "Q. Doctor, please state in a general way as a sanitarian and epidemiologist what is necessary in order to enable one to pass intelligent judgment upon the sanitary character of water?

"A. To form a competent opinion as to the sanitary condition of water and its suitability for use and as a supply of drinking water, one should avail himself of all knowledge obtainable on the subject. A chemical examination may give such results as would indicate that the water is sewage polluted. The discovery of such evidence must always make such a water to be regarded with suspicion. To decide the importance of the suspicion one must determine the condition and the extent as far as possible from other means as to the extent and nature of the pollution.

"There are cases, however, which the chemical analysis will fail to give positive data as to the presence of sewage even when it is undoubtedly present as shown by other data.

"Regarding the bacteriological analysis, I would say that it is frequently possible to obtain results which also indicate the presence of sewage contamination and that such evidence must always render that water suspicious, and that the importance of the suspicion must be determined by a thorough examination as to the source and nature of the source of the pollution, but there are cases in which the results of the bacteriological analysis will not disclose the presence of the ingredients of sewage when it is known by other tests that they are present.

"Indeed, the bacteriological tests have frequently failed to show the evidence of sewage contamination positive in streams which were known to have received sewage contamination. When one must depend upon such data for the determination of the suitability of a proposed water supply, one must use not only the evidence of the chemical and bacteriological examinations, but all data relating to the surroundings of the source from which the water comes.

286 "In determining, however, whether a water in use has been a subject of sewage pollution, unquestionably the most

positive way of obtaining evidence is a careful study of the effects which have been produced by the water upon the persons who have used it. Where a large community uses a water which has been sewage polluted and the injurious ingredients of the sewage still exist in the water it is inevitably shown in its results upon the health of the people. This is so much the case that the statistics of typhoid fever in a community is on the whole the best evidence which pertains to the fact of sewage pollution.

"I would state, therefore, that in my opinion the best test which can be applied to decide whether a given water supply has been infected by sewage is to study the typhoid statistics of the community using the water." (H. E. Smith, Vol. 8, pp. 7701-7702.)

TYPHOID LIVE IN SEDIMENT SIXTY DAYS.

"Q. As sanitary expert, availing yourself of all the chemical and bacterial knowledge which is available to you, what is your opinion as to whether typhoid bacilli living in the sediment of a polluted stream for the period of sixty days would be able to produce typhoid fever if taken into the human system?

"A. I would state it very positively as my opinion that typhoid bacilli living in the sediment of a polluted stream for the period of sixty days would be able to produce typhoid fever if taken into the human system.

"Q. What is your opinion as a sanitary expert as to whether pollution and typhoid fever bacilli coming from the sewers of Chicago, through the drainage canal, deposited in the bottom of the Des Plaines and Illinois rivers can remain there for the period of from thirty to sixty days and yet retain their dangerous qualities as well as pathogenicity?

"A. I will state it as my opinion that I believe when typhoid bacilli are deposited on the bottom of the Des Plaines, or

Illinois river, between Chicago and Peoria for a period of thirty or forty days, they might retain their dangerous qualities as well as their pathogenicity, for I know of nothing which
287 would make it certain that such an organism would meet with any material which would be certainly destructive to it under such conditions." (H. E. Smith, Vol. 8, pp. 7702-3.)

ZONE OF PURIFICATION IN A POLLUTED STREAM.

"Q. From the studies that you have made upon the question of self-purification of running streams, I will ask you to state what is your opinion as to the ability of a running stream to purify itself so as to be free from all pathogenic bacteria that may be discharged therein at a given point so that the zone of purification may be determined to exist at a certain point, and that this given point may apply under all conditions, local and otherwise, at all velocities and volumes of water, all temperatures of weather and seasons of the year?

"A. The conditions affecting the purification of streams from the materials introduced by sewage are so complex that in my opinion it would be impossible by the ordinary methods to determine at what point in the river the purification was always effected, the only way which I can suggest as being entirely satisfactory for the solution of such a problem is the study of the results of the use of such a water by a considerable community. If these fail to show any evidence of a deleterious effect produced by the water, and especially if they fail to show any evidence of typhoid fever, that typhoid fever has been produced by the use of the water, I should think we might reasonably conclude that that point was without the zone of danger during the time of the experiment, but owing to the fact that the chief deleterious constituents of sewage are living organisms, that they may be protected at certain times and in certain numbers

by being enveloped in solid materials which would protect them from the influences ordinarily working against them in streams, it would be impossible to predict with certainty that at some other time than the time of the experiment the water would be perfectly safe at that point.

"It is important to recognize in the question of sewage pollution that the chief injurious ingredients are living organisms and the question of dilution does not come into the discus-
288 sion to anything like the extent that would be the case if the injurious ingredients were inert chemical substances.

"If this were the case it is perfectly certain that we could reach a point where the most harmful chemical substances could be diluted to such a point that it does in any given amount of water in the stream would be without effect upon the living persons, but with regard to a living organism we have to recognize the point that the dilution does not effect the individual organisms, but only its dissemination through the water, and that, therefore, it is possible to find in one portion of the water something that would be deleterious while in other adjacent units of the same size there might not be any." (H. E. Smith, Vol. 8, pp. 7706-7707.)

LONGEVITY OF TYPHOID FEVER GERMS.

"Q. Doctor, state whether or not you have examined the evidence introduced by Doctors Zeit, Jordan and Russell with reference to certain experiments conducted by the use of parchment sacs for the purpose of determining the longevity of typhoid bacilli in the waters of the canal and the Illinois river so as to exemplify true conditions in that water?

"A. I have.

"Q. Have you familiarized yourself with that testimony in this connection?

"A. In a general way I have.

"Q. State, Doctor, whether or not in your opinion these experiments so conducted by Doctors Zeit, Jordan and Russell exemplify actual conditions existing in the running waters of the canal and the Illinois river with reference to the longevity of the typhoid bacilli?

"A. In my opinion these experiments do not exemplify the true conditions, the conditions which exist in the water of the drainage canal with relation to the life of the typhoid bacilli discharged into that as a part of the sewage.

"Q. Upon what do you base this opinion?

"A. The opinion is based on several points: First, the introduction of typhoid bacilli in an artificial culture in such a
289 quantity of sewage enclosed in a parchment sac and protect it. This does not simulate the condition which would exist in the case of typhoid bacilli discharged into sewage and coming from a patient suffering from typhoid fever, in which case the organisms might readily be and frequently are enclosed in fecal masses. Further, the condition of the bacilli in this sac is quite different from that which they would be under if they were free in the stream where they would be free to settle, deposited in the sediment they might then become protected from the influence of the sewage upon them.

Q. State whether or not in your opinion the fact that the bacterial and the chemical condition of the running water in the canal and river remain the same from one end of the day to the other, at the point where these parchment sacs may have been suspended in the water?

"A. In my opinion the condition of the water would frequently change at any one spot owing, as I have said previously in my testimony, to the changeable condition of the discharge which we find coming from the sewers in Chicago.

"Q. Would the fact that there is a different volume or quantity of sewage passing down at night than at day have any effect upon the chemical and bacterial changes of the water?

"A. Yes, the difference in the flow between day and night would make a difference in the composition of the sewage water at any one place, and further, the flow at night is very different in composition from the flow during the day.

"Q. Might not the fact, Doctor, that these bacteria were detained at one point in the parchment sac be harmful to them, while if not so retained in the parchment sac they would pass further down the river in a more favorable media and their longevity be preserved?

"A. Yes, sir. If the destructive action which was found in these cases to be exerted upon the bacilli was due in any way to the concentration of the sewage, the further the bacilli moved down the stream the less they would be subjected to this because of the increased dilution in the lower stretches of the river.

"Q. Doctor, state whether or not in your opinion you know of any bacteriologist, epidemiologist or sanitarians who
290 have limited the longevity of the life of the typhoid germs, either in sewage or sewage polluted water, to less than six days?

"A. I know of no previous experiments which were of such a character as to warrant the experimenters for making such an assertion.

"Q. Do you know of any expert as having written any article or expressed an opinion that the longevity of the typhoid fever germ in sewage or polluted water is within the limit of six days?

"A. I do not recall any such limitation placed by any one.

"Q. I will ask you to state whether or not, Doctor, from your researches in sanitary science and epidemiological work

the opinions based upon the experiments of Doctors Zeit, Jordan and Russell wherein the longevity of the typhoid germ is limited to within six days do not stand by themselves and alone from all opinions that have been expressed and all determinations and observations that have been made by reputable sanitarians?

"A. As far as I know this period of time is shorter than given by other authorities. More experiments of this sort have demonstrated that sewage is in concentrated form detrimental to the life of the typhoid bacteria, but the length of time which bacteria have lived in sewage of the different experiments have been so various that I do not recall a limitation expressed by any standard authorities on this subject.

"Q. Doctor, I will ask you if you know of any instance where typhoid fever germs are known to have lived in sewage longer than six days?

"A. Yes, there are published records of experiments showing the longer period than six days. To refresh my memory a moment the one set of experiments that I have in mind are those of Dr. Horrock's who showed that typhoid bacilli survived in unsterilized sewage a period of fourteen days and there have been other experiments made by different experimenters on this point.

"As I state, I do not know of any one who has felt justified, as the result of these experiments, of limiting the period which typhoid bacilli might survive in sewage when they were
291 introduced in what we might speak of as natural media and under natural conditions.

"Q. You mean by unsterilized sewage ordinary sewage?

"A. Yes, sir, as contrasted with that in which other forms of bacteria have been destroyed before the other experiments have begun.

"Q. Doctor, in his testimony under date of March 1st, last, Professor E. G. Smith was asked by counsel for defendant the following question: 'Assuming that the only pollution of the waters of the Mississippi river above the intake of the St. Louis Water Works derived from the sanitary district of Chicago, and having in mind a large amount of typhoid fever in Chicago, do you or do you not believe that infectious and dangerous pollution might, under existing conditions, find its way into the water supply of the city of St. Louis,' answered as follows: 'The evidence is already introduced in this case, both chemical and bacteriological, showing, in my opinion, some conclusions that the agency of self-purification above in this stream have practically transformed the sewagic matters from the city of Chicago before they reach Grafton, reducing the river at that point practically to the conditions of the streams, and the positive results secured in the experiments of Doctors Zeit, Jordan and Russell upon the liability of the typhoid fever germ in the polluted water of this stream, I do not believe that infected and dangerous pollution might, under existing conditions, find its way into the water supply of the city of St. Louis.' I desire to ask you this same question, and ask you to take into consideration all of the matters contained in the tables found in Streams Examination, introduced in evidence, the tables introduced by Professor Kinnicutt, the tables introduced by Professor Jordan, outside of such tables as are prepared by him and found in Streams Examination, and also to take into consideration what bearing, if any, the experiments of Doctors Zeit, Jordan and Russell have upon actual conditions, and state whether or not in your opinion, under existing conditions, the infected and dangerous matter coming from the sewage of Chicago would find its way into the water supply of the city of St. Louis?

292 "A. Taking into consideration the various data to

which you have called my attention, I would state that I have been able to find no evidence which to my mind is conclusive that the agencies at work in the stream are adequate to destroy the typhoid bacilli which undoubtedly are introduced into the sewage of Chicago and through it into the Illinois river, and therefore, I believe that dangerous and infected pollution might reach the intake of the St. Louis Water Works.

"Q. Under the same assumptions, Doctor, as stated in the last question, do you or do you not believe that such infection and dangerous polluting matters coming from the sewers of Chicago do, under existing conditions, find their way into the water supply of the city of St. Louis?

"A. In answer to your question, I would state that, considering all the data which I have been able to consider as bearing upon this problem, I believe that typhoid bacilli from the sewage of Chicago have reached the intake of the St. Louis Water Works.

"Q. Doctor, Professor Smith, in his testimony under date of March 1st, was asked by counsel for defendants the following question: 'Considering your personal knowledge as a sanitary expert of the typhoid conditions in the drainage district, the existing conditions in said city as to sewers and offals there and the amount of sewage and all existing conditions of the Des Plaines, Illinois and Mississippi and Missouri rivers, and all the conditions existing upon the watersheds of these streams and the tributaries thereof, and all conditions as to the water supply of the city of St. Louis, would you or would you not, beyond a reasonable doubt, attribute the principal portion of the increase of typhoid fever of St. Louis to the infected sewage of the Sanitary District of Chicago, assuming that there has been an increase of typhoid in St. Louis since the opening of the drainage canal?' Now, I will ask you to state, considering your knowledge as a sani-

tary expert of the typhoid conditions in the Sanitary District of Chicago, your knowledge of the pollution and the amount of sewage deposited into the canal, and thence into the Illinois river from the sanitary district, under all existing conditions, on the watershed of the streams of the Mississippi river and its tribu-
293 taries above the Chain of Rocks, and all existing conditions as to the water supply of the city of St. Louis and the general sanitary conditions existing in St. Louis, do you or do you not, beyond a reasonable doubt, attribute the principal portion of the increase in typhoid fever in St. Louis to the infected sewage of the Sanitary District of Chicago, also taking into consideration the results from the various analyses made by analysts, who have testified in this case, as shown by the tables contained in the book known as Streams Examination, the report of the State Board of Health of the State of Illinois and the tables introduced by Professor Kinnicutt and the tables introduced by Professor Jordan and the special experiments carried on by Professors Zeit, Jordan and Russell with reference to the longevity of the typhoid germ as contained in parchment sacs?

"A. I consider the problems involved in your question and would state that in my opinion the data available, especially those relating to the typhoid fever conditions upon the watershed of the Mississippi and Missouri rivers above the intake of the St. Louis Water Works, and the data concerning the occurrence of typhoid fever in the Chicago Sanitary District, are sufficient to demonstrate that the increase in typhoid fever has been due in considerable part at least to infection from the Chicago sewage." (H. E. Smith, Vol. 8, pp. 7709 to 7716, inclusive.)

TYPHOID CONDITIONS AT ST. LOUIS AND THE CAUSE.

"Q. I will ask you to state, Doctor, whether or not you have examined the evidence introduced in this case upon the part of

the complainant and the defendant as to the typhoid mortality in the city of St. Louis for the last six or eight years?

"A. I have.

"Q. I will ask you to state, Doctor, bearing in mind the fact that in 1895 the intake of the water works of the city of St. Louis was changed from Bissell Point to the Chain of Rocks, above the pollution of the Mississippi river by the city of St. Louis, to state whether in your opinion you consider it competent to compare the typhoid fever mortality of St. Louis previous to 1896 with that subsequent to that time in order to de-
294 termine accurately and correctly whether or not an increase of typhoid deaths has taken place in the city of St. Louis since the opening of the drainage canal?

"A. In reply I would state that it is my belief that a comparison of the typhoid fever death rates in St. Louis during the two periods, 1896 to 1899, inclusive, and 1900 to 1903, inclusive, is a competent method of deciding whether there has been an increase of typhoid fever in St. Louis. And, further, I will state that in my belief this is the best method of testing the question as to whether there has been a change in the quality of the drinking water supplied to St. Louis with reference to its infection with typhoid fever.

"Q. You mean by your answer that the manner suggested by you in the answer is the best method?

"A. I mean that the comparison of the typhoid death rate in St. Louis for the two periods is the best method of ascertaining the conditions of the drinking water of St. Louis with reference to this period, of course using in connection with that the data concerning the upper watershed.

"Q. I will ask you to state, Doctor, whether in your opinion and judgment there has been an increase in the mortality from typhoid fever in St. Louis since the opening of the drainage

canal as compared to mortality for the same number of years immediately prior to the opening, such increase being based upon the typhoid mortality per 100,000, or based upon the percentage typhoid mortality.

"A. In my opinion there has been an increase in the typhoid death rate in St. Louis, based upon the mortality per 100,000 population or upon the percentage of typhoid deaths to the total mortality.

"Q. Upon what facts in evidence do you base this opinion?

"A. I base this opinion upon the study of the facts presented from compilations as to the death rates made from the records of the mortuary office and a comparison of the rates for the two periods.

"Q. State, Doctor, whether or not you have examined the testimony introduced in evidence here by respondents showing from the published reports of the Health Commissioner of St. Louis, the total number of deaths reported from remittent,
295 intermittent, typho-malaria, congestive and simple continued fevers, and state whether or not you have examined the compilations taken from the original record in the office of the mortuary officer of the city board of health and made a comparison as to the total number of deaths so reported by respondent's testimony upon these various and respective diseases now designated as nondescript, and state whether or not upon your examination of these records there has been, in your judgment or opinion, an increase in the typhoid in the city of St. Louis since the opening of the drainage canal?

"A. I have examined the data given in the Health Commissioner's report and also those given in the compilation from the mortuary office referred to and have compared the date, and would state that it is in my opinion, based upon these examinations and comparisons that there has been an increase in the

typhoid death rate in St. Louis during the period covered by the four years, 1900 to 1903, inclusive.

"Q. This compilation from the records of the mortuary office of which you speak is the one represented to you as being prepared by Mr. Lochridge, is it not?

"A. That is the compilation which I referred to.

"Q. And Professor Sedgwick—Mr. Lochridge and Professor Sedgwick?

"A. Yes, sir, I understood the compilation was effected by both, and shown me by Mr. Lochridge in particular.

"Q. State, Doctor, whether or not the increase in typhoid fever deaths in the city of St. Louis since the opening of the drainage canal as compared to the same number of years immediately prior thereto has been a decided increase?

"A. I would state that the comparisons which I have made indicate that the increase has been a very considerable one.

"Q. State whether or not an increase in typhoid fever in St. Louis since the opening of the canal is shown to any considerable extent during the winter months?

"A. I would state that the increase has been more noticeable during the winter and spring months than it has during the summer and autumn months.

296 "Q. Doctor, are you acquainted with what is known as the Widal test?

"A. I am.

"Q. Please state the purpose for which this test is used?

"A. It is used as one of the aids in the diagnosis of typhoid fever.

"Q. Will you state as a physician and sanitary expert what effect, if any, the use of the Widal test may have upon the reports of typhoid fever deaths by physicians?

"A. I think that the use of the Widal test has probably not affected very materially the reports of deaths of typhoid fever. Its influence has been more marked in the matter of correct diagnosis of the milder cases of typhoid fever.

"Q. Doctor, I will ask you to state whether or not it is usual in all large communities and cities for health authorities to issue circulars urging physicians to report cases of deaths of typhoid fever to them?

"A. Boards of health in large cities usually have regulations relating to the reporting of lists of certain diseases and among these typhoid fever is always included, and it is common for the boards of health to issue circulars to physicians calling to their attention the regulations pertaining to the report of such cases.

"Q. What in your opinion is the effect of the issuance of such circulars upon the typhoid fever death statistics of these communities and large cities to which you referred in your last answer?

"A. As the circulars relate to the reporting of cases and not at all to the reporting of deaths, and as deaths are usually reported to some regular office, and in many instances separate from the board of health, I see no reason why there should be any special effects shown in the reporting of deaths from typhoid fever from such circulars, and I have in my experience not seen any occurrence which would lead me to suppose that there was any such general effect.

"Q. Doctor, at what ages do the most of the deaths from typhoid fever occur?

"A. The ages of most susceptibility to the typhoid fever
297 are from fifteen to thirty, though there are many cases between ten and forty, the cases under ten and over forty being less common than in the other decade.

"Q. Is not the disease rare in infants or persons over sixty years of age?

"A. Yes, sir, the disease is comparatively rare at these ages.

"Q. Doctor, I will ask you if in your professional work you have become associated with the cost, the manner of operation and cost of operation of filtration plants?

"A. I have had occasion to consider the cost of operating filtration plants, especially as related to the expert over-sight of their operation, this having come to my attention through my connection with several water companies." (H. E. Smith, Vol. 8, pp. 7717 to 7722, inclusive.)

"Q. Dr. Smith, in reference to your testimony on cross-examination upon the longevity of the typhoid fever bacilli in a running stream, I will get you to state whether or not in your opinion the present state of bacteriology is such as to enable a sanitary expert to fix with accuracy the longevity of a typhoid fever bacillus in a running stream, under all conditions and at all possible times, and to state with even approximate accuracy the comparative resistance of a colon bacillus and the typhoid bacillus in a running stream under all possible conditions and at all possible times or to deduce from any experiments heretofore made and introduced as evidence in this case such true and trustworthy information as would enable you to conclude that a sewage polluted river might be used for drinking and other domestic purposes with absolute safety at all times and in all seasons?

"A. My reply to your question is a repetition of points which I have previously taken up, and I would therefore reply briefly that in my opinion the present state of bacteriology is not such as will permit an expert to fix with accuracy the longev-

ity of the typhoid bacillus in a running stream under all conditions and at all possible times.

"Further, that it is not possible to state with accuracy the
298 comparative resistance of the colon and typhoid bacilli in a running stream under all possible conditions and at all possible times; and further, that it is my opinion the present state of bacteriology is such that it is not possible to conclude from bacteriological analysis that a sewage polluted stream might be so purified as to be used for drinking and other domestic purposes with absolute safety at all times and all seasons.

"Q. What effect has a flood upon the watershed of the Des Plaines river and the upper Illinois river upon the sewage of Chicago coming through the canal during the time of such flood?

"A. The effect of a flood at this point would be first to dilute the sewage and hasten the period of passage of it through the river.

"Q. State, Doctor, whether or not, under such flood conditions as mentioned in the last question, it would prolong the life of the typhoid bacilli and other pathogenic organisms?

"A. The trend, as already stated, of bacteriology researches is to show that concentrated sewage has some deleterious effect upon the life of the typhoid bacilli, consequently the effect of diluting the sewage by floods in the upper Illinois river would be to introduce a condition which would tend to increase the longevity of the typhoid bacilli in the water, first, by the dilution of the sewage itself, and, second, by carrying the organisms quicker into the lower stretches of the river where there is more dilution from natural causes.

"Q. Doctor, assuming that the total area of the Illinois river watershed is 32,081 square miles; that the total area of the Mississippi river watershed above St. Louis, Missouri, ex-

clusive of Illinois, is 1,396,170 square miles; assuming that the total drainage area of the Missouri river is 520,086 square miles; assuming that the total urban population, including the Sanitary District of Chicago, upon the Illinois river is 1,843,800; that the total population upon the Missouri river is 552,000 from the mouth of said river to and including the city of Omaha; that the total population upon the Mississippi from Minneapolis is 697,200; please state your opinion as to which of these rivers would be the more unsafe and the more liable to contain
299 dangerous disease producing organisms, basing your opinion upon your knowledge as a sanitarian and epidemiologist, and upon all of the chemical and bacteriological data that have been introduced in evidence in this case, and which you have observed, including the tables in Streams Examination, the health reports of the Board of Health of the State of Illinois, and the report of the University of the State of Illinois, and the tables and the experiments in reference to the colon and bacterial counts introduced in evidence by Professor Jordan, aside from those contained in the books just mentioned, including also the tables of results introduced in evidence as to the longevity of the typhoid germ in the parchment and cellodin sacs and the experiment of Doctors Zeit, Jordan and Russell?

"A. I would state that I have considered the data summarized in your question and would state it as my opinion that the water of the Illinois river would be most likely to contain the largest relative number of disease organisms such as are transmitted by sewage.

"Q. Based upon the same assumptions, state whether or not it is your opinion that the Illinois river does or does not contain more disease producing organisms than either of the other two?

"A. In my opinion the waters of the Illinois river do contain relatively more disease germs such as are transmitted by sewage than the waters of the other rivers mentioned.

"Q. State whether or not that opinion applies to the condition of the water in the Illinois river at its mouth, the Mississippi river at a point immediately above Grafton, and the Missouri river at its mouth?

"A. In my opinion this does apply to the water at the mouth of the Illinois river as contrasted to the water at the mouth of the Missouri, in the Mississippi, in the immediate neighborhood at the points referred to." (H. E. Smith, Vol. 8, pp. 7755 to 7760.)

JOHN W. ALVORD testified in part as follows:

300 "Q. Are you familiar with the results of the experiments found in the reports of the Massachusetts Board of Health in which Hiram T. Mills presents data on the longevity of typhoid bacilli in the waters of the Merrimac river, which results were obtained by him upon analysis and experiments conducted by him?

"A. I am.

"Q. Where, if any, do you find other similar experiments or determinations?

"A. There will be found in the proceedings of the Sanitary Institute of 1899 some experiments made by Dr. Horrocks which appear to be similar to those carried out by Mr. Mills. These experiments are also quoted in Mr. Samuel Rideal's book on sewage, on page 70.

"Q. Are the experiments that you are quoting the experiments of Mills?

"A. No, sir, Horrocks.

"Q. Are you familiar with the sewerage system of Chicago?

"A. I am. A portion of it has been constructed under my design and supervision.

"Q. Under what conditions in your opinion are typhoid bacilli carried away from Chicago so as to approximate conditions which Mr. Hiram F. Mills and Dr. Horrocks used in their experimental work?

"A. The sewerage system of Chicago has very flat gradients and requires frequent artificial flushing. It has been the history of heavy rainfalls in that city that the entire content of the sewers are at such times disgorged into the river bringing into it a mass of pollution which has been accumulating for months together. Before the opening of the drainage canal such periods were extremely dangerous to the water supply of the city, as was shown in the increase in typhoid deaths following the period of such contamination. Such heavy flushings of rainfall occur ordinarily in the early spring or after the breaking up of the winter and at times when the temperature is most favorable to the longevity of the typhoid germ and greatly in-
301 creases for the time being the rate of pollution in the drainage canal and Des Plaines and Illinois rivers.

"In my opinion the action of such a flushing of the Chicago sewer system into the Chicago river with its present large proportion of pure water and low temperature furnishes conditions which parallel or indeed form more favorable conditions to the longevity of pathogenic bacteria than those under which the experimental work above noted were taken. The discharge of this various amount of pollution at times of flood waters appears also to furnish the necessary velocity for rapid conveyance through the drainage canal down the Des Plaines and Illinois rivers to the intake of the St. Louis water supply; the increment of tributary streams also increases the dilution and decreases the chance of toxic destruction of the total number of typhoid

germs present. Such conditions are prevalent in great or less degree during many times of each spring.

"Q. In what you have said of the spring flood, do you have reference to the ordinary spring floods or to the exceptional floods which sometimes occur in this region?

"A. My answer refers entirely to ordinary conditions, such as occur perhaps eight or ten times or more in the spring of each year and often at other times in the year, rather than to exceptional floods such as that of 1888 or 1892 and one or two other heavy floods in which extreme high water marks were reached. Such floods would naturally produce the danger from typhoid pollution to greater distances from the source or origin.

"Q. Are there any other evidences from the testimony introduced in this case and which you have observed which would increase the flow above that mentioned by you?

"A. Yes, sir; in the case of heavy rainfall on the watershed of the Chicago river, it is often necessary, in order to prevent flow into Lake Michigan through the main river, to lower the Bear Trap Dam at Lockport so as to produce greater velocity at all stations down the channel at such times. This undoubtedly aids in the rapidity with which pollution is conveyed away from Chicago down the channel of the Des Plaines and Illinois rivers.

302 "Q. What are the conditions of stream flow in the Des Plaines river?

"A. Below the outlet of the drainage canal at Lockport, the Des Plaines river flows very rapidly to a pool formed by what is known as dam number one at Joliet. This descent over ordinary and normal flow produces rapid velocity and a slight rise, but rainfall will develop velocity in the channel of from 40 to 60 miles per day." (Alvord's testimony, Vol. 8, pp. 7771 to 7774.)

"Q. What are the conditions of flow in the Des Plaines and Illinois river as far down as the Marseilles dam?

"A. Below dam number one and at Joliet the flow again becomes very rapid at times of moderate rises. This flow is slightly checked through Lake Joliet, but there is a further rapidity incurred on its outlet all the way down the mouth of the Kankakee river. Below this point the Marseilles dam slightly checks the current.

"Q. What are the conditions of flow in the Illinois river immediately below the Marseilles dam, below Marseilles at Peru?

"A. Another rapid flow takes place below the Marseilles dam as far down as to Peru, where the influence of the Henry dam is felt.

"Q. State whether or not that is especially true in time of spring floods or rises?

"A. In the time of spring rises the velocity in these reaches is very materially increased, running, as I have said, up to as high as forty to sixty miles a day.

"Q. Are you familiar with the testimony of Mr. Randolph in this case?

"A. I have read Mr. Randolph's testimony.

"Q. Taking into consideration the testimony of Mr. Randolph and the testimony of all other witnesses affecting the subject of hydraulics and sanitary engineering, I will ask you to state, Mr. Alvord, what effect, if any, has the discharge of 250,000 cubic feet of water per minute through the Chicago Drainage Canal upon the dangerous and deleterious substances
303 contained in the sewage discharged into the Chicago river and the drainage canal?

"A. The effect is to materially increase the current of the Des Plaines and Illinois rivers and to carry dangerous pollution

to greater distances and with more rapidity." (Alvord, Vol. 8, pp. 7774-5.)

TYPHOID LONGEVITY.

"Q. What do you consider in your practice and in the recommendations which you make in your profession as a fair statement of the longevity of typhoid organisms which would lead you to give what you consider conservative advice upon this subject?

"A. I have for some years past considered the life of the typhoid bacilli would be from sixty to ninety days under favorable environments, and while large masses of such bacilli might be removed from any given source of supply in a comparatively short time under unfavorable environments, it would not be safe to assume that a water once thus polluted would be safe to recommend for public use under the time given, unless the contamination were eliminated by a carefully designed and properly operated system of purification." (Alvord, Vol. 8, pages 7771-4.)

VELOCITY OF ILLINOIS RIVER.

"Q. Are you familiar with the flow measurements of the Chicago river, the main drainage canal, the Des Plaines river and the Illinois river as described by Mr. Randolph in his testimony?

"A. I have studied them.

"Q. Do you know the discharge of the river at the time these observations were made under Mr. Randolph's directions?

"A. I am unable to find anything in Mr. Randolph's testimony which gives any clue to the amount of discharge *in* the Des Plaines and Illinois river, either at Joliet or Peoria, and therefore am unable to determine what stage the river was in

at the time of his float measurement. The times of these experiments were in July, 1903, as appears by the record, and
304 such time is not covered by the table of discharge given in his testimony at Lockport, nor are any gauge readings given at Peoria where the testimony includes a rating table. I only find the statement that the floats passed over this distance in fifteen days, which is raised to eighteen and one-half days by dividing by eight-tenths.

"Q. What distance do you refer to in your last answer?

"A. The distance from the Chicago river to the Chain of Rocks in the Mississippi above St. Louis.

"Q. As a hydraulic engineer, state whether or not the time limit as ascertained by the floats should be raised in the manner indicated by Mr. Randolph in his testimony, by dividing by .8?

"A. I fail to see the pertinency of his conclusion that a correction should be made, tending to reduce the maximum surface velocity to the mean velocity of flow. The use of the .8 correction, in the manner described in Mr. Randolph's testimony is a very rough approximation, used by hydraulic engineers when surface floats are run in the most rapid part of the channel of a river to determine the average flow for the whole cross-section of the channel in order to get at the quantity passing a given point per second. In the case under consideration, we are not endeavoring to determine the quantity of water passing any given cross-section per second, but the problem presented is what length of time will any given pollution, flowing in mid-channel, pass over the necessary distance from the Chicago river to the Chain of Rocks. This only requires, in my opinion, a determination of the mean velocity of the bore or central section of the stream.

"Q. Do you, as a hydraulic engineer, consider the floats described by Mr. Randolph and Mr. Crane as surface floats?

"A. I should not consider them so. As described in the testimony they appear to be partially submerged, and I believe they give the mean velocity of the central portion of the stream with a fair degree of accuracy.

"Q. Assuming, Mr. Alvord, that these determinations, as made by Mr. Randolph, give the mean velocity of the central portion of the stream, state whether or not in your opinion
305 corrections of the character named and described by Mr. Randolph are necessary?

"A. I believe that they are not necessary.

"Q. What, then, would you consider the length of time that it would take pollution to pass over the described distance as the results of these experiments so conducted by Mr. Randolph at the time such experiments were made?

"A. I should judge that fifteen days' actual time would fairly represent the ability of the water of the Illinois and Des Plaines rivers to carry pollution to the Chain of Rocks at the stage when the experiments were made.

"Q. State whether or not in your opinion the mean flow of the stream should be considered as the time element in the passage of sewage and pollution from a given point to a point below on that stream?

"A. I think it should not. Pollution is carried much faster on a given stream than would be indicated by a mean average flow. It may not be carried as fast as the very fastest thread of the stream, but it is certainly carried as fast as the average velocity of the central or fastest part.

"Q. Have you examined the evidence of the experiments conducted by Professor Van Ornum, described in the records of this case?

"A. I have.

"Q. Taking into consideration the testimony of Mr. Randolph in the experiment which he conducted with the floats in obtaining the velocity of the water in the Illinois river, in July, 1903, I will ask you to state what conclusions you draw from a comparison of the respective velocities obtained by Mr. Randolph and Professor Van Ornum, and taking into consideration the evidence as to the gauge readings that existed for a period prior to these experiments and subsequent thereto, as introduced in evidence by Mr. Randolph and Crane, in what way do these experiments represent the minimum or maximum velocity of the water in the Illinois river?

"A. I should judge, in answer to the first part of your question, that the float experiments of Mr. Randolph in July,
1903, were undertaken at a very much lower stage of the
306 river than were those of Professor Van Ornum in March,
1903, as Professor Van Ornum finds materially greater velocity than does Mr. Randolph.

"I also observe that Professor Van Ornum commenced his float experiments in a low stage point, between two March rises in the river. There were flowing over the Bear Trap Dam at the time he commenced his operations, as taken from the figures in the tables in the evidence, 289,000 cubic feet per minute, which gives a rather low velocity in the drainage channel. About 394,000 cubic feet per minute was passing over dam number one at Joliet at the same time.

"Eight days prior to this, and on the 8th and 9th of March, 707,000 and 718,000 cubic feet per minute, respectively, passed over the dam at Joliet.

"Five days after Professor Van Ornum commenced his experiments, or on the 21st and 22nd of March, 764,000 and 711,000 cubic feet per minute passed over dam number one, or nearly double the amount of flow, both earlier and later, was in existence than occurred when his experiments were commenced.

"It would seem, therefore, that Professor Van Ornum's experiments were undertaken at a very comparatively high stage but not by any means the highest stage so far as the drainage channel and the upper portion of the Des Plaines river are concerned.

"In passing Peoria, Professor Van Ornum observes the stage of water upon the gauge, which I find, by referring to the table of flow submitted by Mr. Jacob A. Harmon, in this case, gives a flow of about 50,000 cubic feet per second. This flow would correspond to a stage of the river which is somewhat overflowing the banks in the lower courses.

"As Professor Van Ornum used submerged floats, I feel that the actual time traveled by the velocity floats represents fairly the mean velocity of the pollution vehicle, and I take the total time as represented by these floats as representing the total time which it requires to travel the total distance under consideration, with the exception that I believe that there are times when the velocity in the drainage channel in that portion
307 of the river immediately below the Bear Trap Dam is greater than those which he found.

"In 1898 I was engaged as consulting engineer for the State Board of Canal Commissioners in litigation with the Sanitary District of Chicago over certain water powers, and these channels below the Bear Trap Dam, and had occasion to very carefully study the velocities and stages and various stages in this vicinity. I have, therefore, verified Professor Van Ornum's float experiments in this vicinity, recognizing them to correspond with what I know to be the facts in the spring rises in the upper portion of the course under consideration. Below Lake Joliet I have accepted Professor Van Ornum's experiments to the Chain of Rocks as being properly indicative of what might happen in ordinary spring floods.

"From Bridgeport to the Chain of Rocks I find that 9.8 days is consumed, using mean velocity to Joliet, and Professor Van Ornum's float experiments from there to the Chain of Rocks. I do not consider that this is the shortest time in which pollution would travel this distance, but believe, that the maximum flood, such as occurred in 1892, would adduce this time to at least eight days and possibly slightly less. The 9.8 days represents to my mind a stage which could be counted upon as occurring a number of times in each year.

"Q. State whether or not you have had occasion to examine and study the velocity and stages of the rivers in question, in the course of your professional career.

"A. I have.

"Q. From what you have said of your observations of the testimony introduced in this case and of the testimony of Mr. Randolph, from his float experiments, state whether or not in your opinion the float experiments of Mr. Randolph represent a minimum velocity of the water in the Illinois river from Chicago to St. Louis at all times of the year?

"A. Not having been able to ascertain the specific stage at the time of Mr. Randolph's experiments, I should be unable to state positively that his experiment was made at the minimum stage of the river, but speaking generally it is my impres-
308 sion that it was and represents the average of the minimum velocity in the ordinary dry seasons of the year between the Chicago river and the Chain of Rocks." (Alvord's testimony, Vol. 8, pages 7775 to 7780, inclusive.)

SEPTIC ACTION.

"Q. State whether or not you have given attention to the development of processes of sewage purification by means of septic tanks?

"A. I have given particular attention to the development of septic tanks and have designed some ten or fifteen plants for municipalities in which a septic tank has been employed on my recommendations. Of these plants eight septic tanks have been constructed under my immediate supervision for different municipalities and have been in operation for periods ranging from one to four years. Two of these plants have been under my immediate supervision ever since construction, and I have watched the operation of others.

"Q. What is septic action and how long should sewage remain in a septic tank in order to obtain practical results from a sanitary standpoint?

"A. Septic action is the process of breaking down the organic matters in sewage by micro-organisms or their products in the absence of oxygen. This process is continuously brought about by allowing the sewage to come nearly or quite, to a state of rest in deep tanks and allowing it to remain so until the dissolved oxygen present, if any, is exhausted and until the solid particles of the sewage have been attacked and broken up more or less in soluble compounds. It is desirable in order to provide favorable conditions for this process that the temperature remain as constant as possible and very high, and it is preferable that light and air should be excluded, although this is not absolutely essential. The proper period of rest necessary to get the best results will vary with the composition of the sewage, its temperature and character. It has been found desirable to adjust the rest period so that the temperature and other variables can be controlled and the period of rest
309 adapted to the concentration of the sewage and its relative flow proportioned to the tank in which it is confined.

"Q. State whether or not flowing sewage ordinarily undergoes the process of septic action?

"A. It does not ordinarily.

"Q. State whether or not diluted sewage flowing in open channels simulate septic tank conditions?

"A. It would not. The flow of liquids through open channels tend to bring all portions of the liquid from time to time to the surface, where it may receive oxidizing influences tending to retard septic action.

"Q. Are you acquainted with the present physical condition of the Chicago Drainage Canal?

"A. I am.

"Q. Please compare the conditions existing in the Chicago Drainage Canal with those of a true septic tank?

"A. In the Chicago Drainage Canal we have a large volume of diluted sewage flowing at the rate of one to three feet per second, giving ample opportunity for renewing its dissolved oxygen. And we have this action further increased by the opportunity of the wind to stir the surface of the stream and still further oxygenate it.

"We have also an opportunity for exposure to low temperatures, light, etc., which are detrimental to the septic action.

"Q. State whether or not septic action to any considerable extent takes place in the sewage of Chicago during its passage through the drainage canal?

"A. It does not.

"Q. Are you acquainted with the chemical data that has been introduced in evidence by the defendants?

"A. I am to some extent.

"Q. State whether or not in your opinion the chemical data introduced by the defendants with reference to the character of the contents of the Chicago Drainage Canal, indicate any septic action has taken place?

"A. My opinion is that they do not. The amount of improvement in the sewage in its travel of the drainage canal found by Professor Kinnicutt in his testimony in this case,
310 would seem to me to be largely due to aerobic action. Possibly there is anaerobic action to a very limited extent, but not enough in my opinion, to influence the results perceptibly.

"Q. State whether or not the extensive dilution of the sewage of the city of Chicago, by the richly oxygenated water of Lake Michigan, is a useful preliminary to septic action?

"A. It is not. On the contrary it is distinctly opposed to the inception of septic action. In good practice, in the designing of septic tanks, it is the endeavor always to bring the sewage into the tank as quietly as possible, undiluted with surface or underground waters containing undissolved oxygen.

"Q. State whether or not you were familiar with the South Branch of the Chicago river prior to the opening of the drainage canal.

"A. I am.

"Q. What was the condition of that part of the river at that time?

"A. It presented all the characteristics of septic action to a marked degree.

"Q. What were those characteristics?

"A. The absence of marked current, and the presence in certain places of more foul products and considerable surface scum, the absence of undissolved oxygen as shown by chemical examinations and the visible production of gases bubbling up from the depths below, such as characterize the septic tank when in active reduction of its organic matter.

"Q. State whether or not in your opinion, typhoid germs are now more able to survive longer under the present condition

of sewage dilution in the drainage canal than they could formerly have survived in the South Branch of the Chicago river or in the Illinois and Michigan Canal?

"A. I believe that typhoid germs can survive materially longer under the present conditions than was the case formerly in the Illinois and Michigan Canal, and the South Branch of the Chicago river." (Alvord, Vol. 8, pp. 7787-7791.)

311 CHICAGO SEWAGE CAN BE TREATED.

"Q. Mr. Hering, who testified for the defendants on March 10th last, was asked by counsel for the defendants the following question: 'From what you know of the question of disposal of sewage and from the knowledge which you have in regard to the drainage canal, the manner in which it is operated, and taking into consideration the experience you have had since you made your preliminary report, what changes would you recommend for the sewage disposal of the city of Chicago if the same problem was submitted to you now which was submitted to you in 1886, as a sanitary and hydraulic engineer?' Answering this question, Mr. Hering said that in considering the several ways of disposing of the sewage of Chicago, from personal knowledge and experience, my recommendation would be that the sewage of Chicago should be disposed of by dilution through the channel substantially as that which has been constructed with the subsequent discharge into the DesPlaines and Illinois rivers.' Thereupon the following further question was asked him: 'In the study of this problem have you discovered anything that would change the view expressed by you in your preliminary report at that time?' In answer to which question Mr. Hering said: 'I have not.' I will ask you, Mr. Alvord, to state whether or not there are in your opinion, any practical modifications of the existing system of sewage disposal of the city of Chicago

by which the drainage canal could still be employed for keeping the Chicago river in an inoffensive condition and yet avoid the pouring of unpurified sewage into and through the canal over the Bear Trap Dam at Lockport and into the DesPlaines and Illinois rivers?

"A. I am of the opinion that it is entirely practicable to retain the drainage channel so that it can be still employed for keeping the Chicago river in condition and yet avoid pouring unpurified sewage into and through the canal and into the Des-Plaines and Illinois rivers, and I would suggest as the proper remedy the construction of suitable intercepting sewers along the Chicago river and its branches, by means of which the
312 sewage flow of the city may be kept out of the Chicago river and lead along its banks to the upper end of the drainage channel beyond Bridgeport and then raised by a suitable pumping station, preferably operated with water power derived from the drainage canal to and into a suitable purification plant constructed in accordance with the latest bacteriological principles and effectually remove from such sewage all or practically all of its organic wastes and pathogenic bacteria, and emptying the effluent from such sewage plant into the drainage channel near Bridgeport, to be conveyed through the same and through the DesPlaines and the Illinois rivers in a harmless and purified state.

"Q. State whether or not you have considered the relative expense of such a plant as you have described in your last answer?

"A. I have considered the expense in a general way, and am of the opinion that such intercepting sewers and purification plant could be constructed as an expense no greater than that necessary to widen the South Branch of the Chicago river in order to increase its flow of dilution water to the requirements of dilution.

"And I am further of the opinion that the operating expense of such a plant would be no greater than the operating expense of the present system of pumping sewage and the necessary dilution water through the same for the northerly and southerly portions of the sanitary district and the dilution water for the proposed additions to such sanitary district." (Alvord, 8, pages 7794 to 7796.)

PROF. W. T. SEDGWICK, testified in rebuttal, in part, as follows:

BASIS OF SHOWING TYPHOID MORTALITY.

Q. Professor, I will ask you to explain why you have used in your testimony in this case the percentage mortality basis in determining the increase or decrease of typhoid fever death rate in the city of St. Louis?

313 "A. I think I stated briefly when testifying in chief my reasons for using the percentage mortality basis, but in as much as witnesses for the defendants have criticised this method, I desire to state further my reasons and to show by two simple charts (Charts on pages 7957-7958) that in the case of two cities of closely similar population, St. Louis and Boston, this method yields results similar to those which would be obtained by the deaths per 100,000 basis, that is, the basis of deaths to population. Both methods are in common use, and it is to a considerable extent a matter of choice or taste whether one shall employ one method or the other. In favor of the percentage mortality method is the fact that it eliminates from the problem altogether the question of population, and inasmuch as population in many communities, especially between census years, is a most uncertain matter, I personally make frequent use of the percentage mortality method.

"On the other hand, there is no doubt that under certain circumstances the other method furnishes more instructive and sometimes more accurate results. This is particularly true when the population is accurately known.

"In order, however, to show that in the present case the method of percentage mortality, that is to say, the proportion of the typhoid deaths to the total number of deaths is neither inaccurate nor misleading. I have prepared the charts above referred to. One of these, entitled 'Typhoid percentage to total mortality,' is constructed upon the basis which I employed in my testimony in chief and upon this chart I have indicated not only the typhoid fever death rate computed in this way for the city of St. Louis, but also for that of Boston, a city of almost exactly the same size.

"The second chart, entitled 'Typhoid death per 100,000 population,' is constructed upon the other plan and represents the deaths from typhoid fever in St. Louis and in Boston for the same years covered by the first diagram, namely ten years, 1884 to 1894. These charts show, I think, clearly the fact that no misleading conclusion could have been drawn from my ori-
314 ginal testimony, for both demonstrate clearly and to the same effect the essential fact as testified to at that time."
(See Sedgwick's testimony, Vol. 8, pages 7955-6-7 and 8.)

NO RIVER IN GREAT BRITAIN LONG ENOUGH FOR SELF-PURIFICATION TO TAKE PLACE.

"Q. In the testimony of defendants, taken on February 3rd, 1904, Professor Jordan was asked the following question: 'Professor Sedgwick states * * * the River Commissioners of Great Britain, in a report published by them in 1874, stated that there is no river in England long enough to purify itself from any sewage admitted to it even at its source. That stands as

one of the axioms of sanitary science today, that those River Commissioners, in 1874, I think it was, made the statement that there is no river in the United Kingdom, I think they said, long enough to purify itself of any sewage introduced into it, introduced at its source and of course some of the rivers of the United Kingdom are very long.' Professor Jordan stated that he was not able to find this quotation, saying that the closest that he could find to it was the following: 'It will be safe to infer that from the above results there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation.' Professor Jordan was further asked, 'What is the difference between the expression 'to effect the destruction of sewage by oxidation,' and the expression 'to purify itself of any sewage introduced into it at its source.' "

"Now, Professor Sedgwick, I will ask you to state whether or not the quotation as you gave it from memory or the version suggested by Professor Jordan is the nearer the true quotation and was essentially correct?

"A. I think that the quotation which I made from memory was nearer the original, which I will now read from the report referred to by myself, and I presume by Professor Jordan, namely the Sixth Report of the Rivers Pollution Commission appointed in 1868, which inquired into the best means of
315 preventing the pollution of rivers. This report was published in London in 1874 as one of the British Blue Books, and on page 427 occurs the statement to which I referred, as follows:

"There is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it, even at its source."

"I may say that I am not surprised that Professor Jordan had difficulty in discovering this precise quotation, inasmuch

as the book is a large one and is not at all well arranged. I may say further that the popular version of the statement made by the Commissioners is simply that 'There is no river in England long enough to purify itself.' It is easy to see how this shorter version has arisen, and if it were simply made to run 'There is no river in the United Kingdom long enough to purify itself,' I believe that it would substantially represent the true doctrine of sanitary science today." (Sedgwick, Vol. 8, pp. 7959-7960.)

LIFE OF TYPHOID IN DRAINAGE CANAL.

"Q. Professor Sedgwick, have you examined the testimony of Professor Jordan, Dr. Zeit and Professor Russell, concerning their experiments upon the longevity of the typhoid germs in parchment and cellodin sacs and agar blocks suspended in Lake Michigan, the Chicago river, the Drainage Canal and the Illinois river, and all other similar experiments made by these gentlemen and introduced in evidence?

"A. I have.

"Q. State whether or not you are able from the determinations made by them in the above connection to formulate an opinion as to the longevity of typhoid organisms contained in these waters?

"A. No, I should not be able either to form or to formulate a comprehensive opinion from these experiments alone. It is clear, of course, that, as shown in these experiments, the germs survive for certain lengths of time, but I should be unable to conclude from the experiments that under different conditions typhoid fever germs might not survive for longer times. The experiments appear to me to have been very ingenious and interesting, but not by any means conclusive, upon the
316 whole subject of the longevity of typhoid fever germs in moving bodies of sewage or water.

"Q. State whether or not in your opinion these experiments just referred to simulate natural conditions in the water?

"A. Undoubtedly they were devised as far as possible to do this, but in a great deal of experimental work the result of the experimenter falls short of his endeavors. I do not see how it is possible in the present state of bacteriology to devise any series of experiments which shall accurately and completely imitate the infinitely various conditions of running streams, and particularly streams such as the Chicago river, the Chicago Drainage Canal and the Illinois river, subject as these are, to an endless variety of alterations, in their physical, chemical and bacteriological conditions.

"For example, these experiments were carried on in cold weather, I believe, but even if they had been carried on for an entire year, under all actual variations and conditions, they would still, in my judgment, have been incomplete, for the reason that in other years under other conditions, organisms as sensitive as typhoid fever microbes are, might have encountered environments which would have materially altered the results. Besides, it seems to me that the conclusions arrived at by these able investigators indicate a shortness of life of the typhoid fever germs, which is not in harmony with the longevity naturally deducible from the experience of mankind with epidemics due to typhoid infected waters, and while evidence of this kind is hard to reduce to a strictly scientific basis, it has, I believe, nevertheless great value, for the reason that it is the outcome of the experience of the race.

"Furthermore, the results of these experiments, broadly speaking, indicate a considerably shorter period of life for the typhoid fever germs in sewage and water than has been found by the majority of previous investigators. My own opinion is that a greater number of experiments, conducted for a longer

time, and under different conditions, would not fail to show that typhoid fever germs may, and do, live in sewage and running streams a very much longer time than was found in these particular experiments.

317 "Q. In what particular way did these experiments fail to represent true natural conditions?

"A. I should not say that these experiments failed to represent natural conditions any further than many experiments must necessarily fail to imitate natural conditions. I mean by that, that these experiments were undoubtedly well planned and well conducted, but it is easy to suggest a great number of points in which they do nevertheless fail, the principal failure being to duplicate all the various conditions of the running stream. Some other matters have already been mentioned by witnesses for complainant in rebuttal, such, for example, as the fact that the germs in the several experiments were anchored, so to speak, at fixed points, instead of being allowed to float down the stream with a particular body of water. Anyone can readily see that this is an unnatural condition, especially in the case of the Drainage Canal, and the Chicago and Illinois rivers, for the reason that the chemical composition of these bodies of sewage and water is subject to frequent changes. If, for example, the waste from a large industrial establishment should be turned into the Chicago river at any particular moment, the water which received it would vary materially in chemical composition from the water just preceding and just following it. For this reason sacks or blocks at anchor are probably exposed to a great variety of changes than they would be exposed to if they were to float down the stream with one particular body of water.

The sewage discharged from a city at night is a very different body, chemically, from that discharged by day. The sew-

age discharged during a heavy storm is very different from that discharged in dry weather. Again, the seasonal conditions must be taken into account, and in the case of the Illinois river physical conditions, such as floods in the tributaries, or the overflow of lakes upon these tributaries, bringing in new materials and a strange bacterial flora. These and many other things which I need not, and could not mention, undoubtedly play a highly important part. The trouble is that in trying to fix the longevity of typhoid fever or any other microbes we are dealing with

318 extremely sensitive and almost infinitesimal organisms which we have only within the last few years learned to recognize at all, and have not yet by any means learned to know thoroughly. I believe, therefore, that while the experiments of the experts for the defense are interesting, ingenious and important in the science of bacteriology, they should not be allowed to have too much weight in determining the issues in this case.

"Q. Assuming, Professor, that the longevity of a typhoid fever germ in an open sewer, such as the Drainage Canal, as characterized by different witnesses, and as limited by the experiments of Doctors Zeit, Jordan and Russell to from two to four days, in what respect is the credibility of these experiments reflected upon by the ordinary, usual and general practice of sanitarians in the construction and recommendations for the construction of plants for the treatment of water for domestic purposes, which has been subjected to sewage pollution?

"A. As I understand the question, it is my opinion that their results are so far out of harmony with the results of previous investigators and so contrary to the prevailing opinion upon this subject which forms the basis of the practice of sanitarians and engineers in forming their opinions concerning the availability of polluted streams for drinking and other domestic

purposes, as to throw grave doubt upon the results, and therefore upon the conclusions to which these naturally lead." (Sedgwick, Vol. 8, pp. 7960-7963.)

TYPHOID IN ST. LOUIS DUE IN PART FROM CHICAGO SEWAGE.

"Q. Professor, have you examined the testimony of Professor Mason with reference to the effect that increased typhoid fever in the city of Chicago would have upon typhoid conditions in the city of St. Louis, assuming that the germs of this disease pass from Chicago to St. Louis?

"A. I have.

"Q. State whether or not, based upon the chemical and bacterial analyses that have been introduced in evidence in this case on the part of the respondent, and upon the physical conditions and surroundings of the Illinois river, including the sani-
319 tary district of Chicago, what effect would you reasonably expect an increase in typhoid in Chicago to have upon typhoid conditions in St. Louis?

"A. Taking into consideration the distance between the two cities and the time required for the passage of typhoid fever germs from Chicago to St. Louis down the Drainage Canal, the DesPlaines, Illinois and Mississippi rivers, and taking into consideration also the character of the Drainage Canal and of the Illinois river, and considering also the fact that the water drawn from the intake at the chain of rocks by the city of St. Louis for its public supply is now, and long has been, subjected to extensive sedimentation, I should not expect to find any close correspondence between the details of the typhoid fever curves of the cities of Chicago and St. Louis over such periods.

"We must also take into consideration the fact referred to by Professor Zeit in his testimony, that typhoid germs ar-

riving at the city of St. Louis might act through the formation of local foci of infection, the time required for which must always be of uncertain duration.

"I should therefore expect to find a correspondence between the prevalence of the diseases in the two cities, in general and broadly speaking, only when considerable periods were dealt with. It is, of course, probable that a very severe epidemic of typhoid fever in Chicago would make itself felt in St. Louis in such a way that cause and effect could be clearly connected, but here again much would depend upon the season of the year, the rate of flow in the Illinois and Mississippi rivers, the local conditions of the sewage, and the efficiency of sedimentation in the sedimentation basins of the water works of St. Louis. I am therefore not surprised to find that the curves of Professor Mason do not indicate any conspicuous and constant relation between waves of typhoid fever in Chicago and similar waves in St. Louis. I do believe, however, that by taking long periods and averages we ought to see and do see a definite connection, as for example, when comparing typhoid fever in the years following 1900, with those preceding that date." (Sedgwick, Vol. 8, pp. 7963-7964.)

320 TESTS ON BACILLI COLI COMMUNIS.

"Q. State whether or not you have examined the evidence of Professor Jordan and Professor Burrill upon the colon tests made by them and their evidence in connection therewith?

"A. I have.

"Q. State, Professor, from the consideration of these colon tests and tables so introduced by Professors Jordan and Burrill, together with the other testimony upon the chemical and bacterial data, your conclusions as to the appearance of patho-

genic bacteria in the waters of the Illinois river at its mouth, originating at Chicago?

"A. The tests applied by Professor Jordan and Professor Burrill to the water of the Illinois river, while they show a very great decline in the numbers of these organisms present in the lower reaches of the river at the times when the specimens examined were taken, in those particular specimens, do not, in my opinion, enable any one to form an accurate opinion as to the presence or absence of typhoid fever germs in the waters of that river at those points.

The reasons for my opinion are, first, that only a comparatively small number of specimens was examined, and from the nature of the case such specimens only imperfectly represent the true and complete character of the streams at all times and all seasons, and, second, that while the colon test is a valuable aid in sanitary water analysis, it is by no means a sure and perfect measure of the presence or absence either of the bacillus coli itself or of the typhoid fever bacillus. It is not a sure and perfect test for the colon bacillus at all times, because experiments have shown that this organism sometimes fails to make its appearance in the tests applied, even where it is proven to be present by a further study of the same specimen. And it is by no means a sure test of the presence or absence of the typhoid fever germ, not only for that reason, but also because it is not yet established beyond all reasonable doubt that the life of the typhoid fever germ so closely resembles that of the colon
321 bacillus as to be fairly represented by it under all conditions at all times and all seasons.

"I am therefore of the opinion that while the experiments of Professors Jordan and Burrill throw great light upon the process of bacterial purification going on in the Illinois river, they do not by any means establish the fact that typhoid fever is

completely or effectually removed from the waters of that river before it empties into the Mississippi at Grafton." (Sedgwick, Vol. 8, pp. 7965-6.)

TYPHOID INCREASE IN ST. LOUIS.

"Q. State whether or not you have examined the tables and charts introduced in evidence by Mr. Lochridge, based upon the mortality record of typhoid, typho-malarial, intermittent, remittent, congestive and continued fevers and enteric and bilious fevers?

"A. I have, and I am thoroughly familiar with them, for the reason that Mr. Lochridge has frequently consulted me with reference to them, and their preparation, which was begun and carried out by him at my request, and with my constant advice and supervision.

"Q. Will you examine those charts and tables and state what they show with reference to an increase or decrease in typhoid fever since January, 1900, to December, 1903, inclusive, as compared to a corresponding period immediately preceding, and taking into consideration in this connection the deaths reported from malaria, intermittent, remittent, typho-malarial, congestive and continued fevers?

"A. The typhoid fever deaths taken by themselves and alone show a marked annual increase during the last four years; that is to say since the opening of the Chicago Drainage Canal. This increase, moreover, is not only considerable from year to year during this period, but it is much more marked than it was during the preceding period. In fact, during the four years, 1896 to 1899, inclusive, typhoid fever in the city of St.
Louis may be said to have been stationary or very nearly so,
322 and not at all excessive, the annual death rate from typhoid
fever measured either by percentage mortality or by com-

parison with the total population having been such as, broadly speaking, prevails only in cities having good water supplies. But during the last four years of the period under consideration, typhoid fever in St. Louis has risen far above this level, until it stands at the end of the period higher than at any time during the whole period under consideration.

"The testimony introduced by the defendants having tended to show a possibility of the transfer of deaths from other diseases, especially remittent, intermittent, typho-malaria, congestive and simple continued fevers into the typhoid group, especially in the latter years under consideration, I have examined with special interest Mr. Lochridge's analysis of these several non-descript fevers, or rather of the deaths attributed to them, and tabulated by him upon his charts; for it was a possibility that some such transfer might in fact have been made. The unquestioned improvement in medical education which has been going on for the last twenty years, especially after the introduction of the Widal test, might conceivably have had some influence in causing such transfer, the effect of which would have been to increase the number of deaths attributed to typhoid fever in the latter years of the period under consideration. Any such change must, however, of necessity, have been gradual, while in point of fact the increase of typhoid fever in the city of St. Louis was sudden, sharp and has thus far been continuous. In the second place the Widal test, having been introduced by the Board of Health of the city of St. Louis early in the year 1897 should have made its influence felt, if it had any in the direction indicated, previous to the year 1900, but no such influence is visible in the figures compiled by Mr. Lochridge or upon his charts. It is not, however, by any means clear that the Widal test would always tend to increase the total deaths from typhoid fever for, while it unquestionably clears up the diag-

nosis, and in some cases, perhaps, leads to the recording of deaths as due to typhoid fever which with its use might have been referred to some other disease. The Widal test works also in the opposite direction, giving negative results in many sus-
323 pected cases and removing from the typhoid group deaths which without its use might have appeared there. It is important to note that only from five to ten per cent of the specimens sent in by physicians for the Widal test ordinarily prove positive and it is particularly important to note that in the city of St. Louis a large number of cases diagnosed as remittent fever, malaria and typho-malaria fever, the blood from which was subjected to the Widal test, failed to give any typhoid reaction.

"Again, Mr. Lochridge's compilations and charts throw great light upon the whole matter by enabling us to consider the ages of the decedents from the various diseases referred to, as well as the seasons in which they died; and a careful comparison of the incidence of death at the different ages and months, enables one to show beyond doubt that, even if a considerable proportion of the deaths from remittent, congestive and intermittent fevers which occurred previous to the year 1900 were by better diagnosis removed from those groups in the remaining years, these were not in point of fact transferred to the typhoid group.

As to the matter of season it is important to observe in the first place that Mr. Lochridge's charts indicate a considerable increase in typhoid fever in the city since January 1, 1900, at all seasons, but especially that this increase has been greater in the winter and the spring, than it has in the summer. This is one of the most important facts which I deduce from the charts, for it shows in the first place, that the increased number of deaths found in the typhoid group is almost certainly, as proved by this test alone, not due to a transfer of malarial deaths to the

typhoid column since malaria is not prevalent in the winter. In the second place, this winter increase is extremely important, for the reason that during the winter months the Missouri river is a less important factor in the water supply of St. Louis than it is during the summer months; so that this winter increase must have had its origin elsewhere than in the Missouri river. I do not think it necessary for me to dwell longer upon these charts which Mr. Lochridge has already explained in detail, and I believe that I have stated some of the principal conclusions to be drawn from them. I will, however, say before leaving
324 them that they appear to me to prove beyond all reasonable doubt that the typhoid fever increase in the city of St. Louis since January 1, 1900, has not been due to any transfer of deaths from remittent, intermittent, congestive, typhoid-malaria, or simple continued fevers into the typhoid fever group.

"One thing more I ought to mention. Mr. Lochridge has made a correction indicated by dotted lines upon some of the charts for the localized epidemic of typhoid fever which occurred in November and December, 1899, and the deaths from which continued, apparently into 1900. This epidemic, as I have taken pains to inform myself by inquiry of physicians in different parts of the city and otherwise, was localized in the west central portion of the city, was such that in my judgment could not have been due to a general pollution of the public water supply. I believe that it was due to milk, but I am unable to state this positively.

"Q. In answer to your last question, the last question of mine, did you take into consideration also the age of the patients dying?

"A. I believe that I briefly referred to that matter which is of special importance as establishing some of the facts and conclusions which I mentioned, in the deaths recorded as due

to some of the fevers not typhoid. A comparison of the ages of decedents from these diseases and of those from typhoid fever makes it perfectly clear that is, as sometimes happens, the number of deaths from a disease in the first group has declined, this can not be because deaths from this particular disease have been transferred to the typhoid fever group, for the reason that no deaths of corresponding ages can be found in that group.

"Q. State whether or not, professor, from these charts and tables introduced in evidence by Mr. Lochridge, which are based upon the typhoid fever deaths and deaths from the nondescript fevers show in any way an increase of any character since the opening of the Drainage Canal which may be due to the influx of people on account of the construction of the Louisiana Purchase Exposition?

325 "A. Replying to this question I may say that I have given in the past some attention to the influence which expositions of this kind have upon typhoid fever death rates, for the reason that in the year 1892 I studied the typhoid epidemic in Chicago, as I have already testified in this case. That date was just before the opening of the World's Columbian Exposition, and it was frequently alleged that the excess of typhoid fever in Chicago at that time was due to the influx of workmen and others preparing for that exposition. In studying this question I also examined the typhoid fever mortality of Philadelphia before, during and after the Centennial Exposition of 1876, and found that, while typhoid fever was excessive in Philadelphia during the year of the exposition, it was not much, if any, higher than usual during the years immediately preceding it. Further investigation led me to conclude that the excess of typhoid fever in Chicago just before the opening of that exposition was not due to any influx of outsiders, but to a grossly contaminated

water supply, and this latter opinion has come to be generally accepted as true. In fact, during the exposition itself the typhoid fever in the city of Chicago was decidedly lower than it had been in the preceding year, owing to the energetic measures taken by the exposition and city authorities for improving the public water supply. In view of these facts I am of the opinion that no important portion of the increase in typhoid fever in the city of St. Louis since January 1, 1900, can reasonably be attributed to the influx of workmen or others connected with the World's Fair.

"Q. From the examination which you have made of the charts introduced by Mr. Lochridge, and from your general information upon the subject, epidemiologically and otherwise, state what effect in your opinion circular letters sent out by the health department from year to year has had upon the mortality records of the city of St. Louis and especially with reference to typhoid conditions?

"A. I have had much experience with boards of health and their workings, and in many cities I have had occasion to observe that circulars of this kind, issued by boards of health are generally ignored altogether. I am of the opinion that no
326 circulars issued by any board of health and urging the reporting of *cases* of typhoid fever could have any influence upon the reporting of *deaths* from that disease, for the reason that physicians are legally bound to report deaths any how, before a burial permit can be obtained from the board of health or other municipal authority. Such circulars, in fact, sometimes tend to diminish the number of deaths reported from typhoid fever rather than to increase them. I have, indeed, known of a few instances in which a physician had reported a death really due to typhoid fever as due to some other disease because, having failed to report it while living as a case of infectious disease,

as required, he feared to incur the displeasure of the authorities if he should report it as a death from that disease, and thus possibly subject himself to a summons, a fine, or other penalty."

(Sedgwick, Vol. 8, pp. 7966-7970.)

SAPROPHYTIC INFLUENCE ON PATHOGENIC BACTERIA.

"Q. Professor, Dr. Zeit, in his testimony along with other witnesses for the defendant, attributed extensive destructive effects upon typhoid fever germs in sewage and sewage polluted water to the toxic products of the saprophyte in sewage. State whether or not bacteriologists and epidemiologists agree with him as to these facts?

"A. Unquestionably some would agree with him. Others, like myself, do not accept this view, and against Dr. Zeit's theory I may quote the following experiment made by myself and one of my students, Mr. D. D. Jackson, as long ago as 1893, In this experiment we undertook to test the very point under consideration. A portion of sewage was carefully freed, by filtration, from all microbes present, whether saphrophytic or parasitic. The filtrate was proved to be free from such germs, but was otherwise ordinary sewage, that is to say it contained the toxic products, if any, of the saprophytics which it contained in abundance, and which had been removed by filtration. A portion of this filtered sewage was then seeded with ty-
327 phoid fever microbes, to the number of 329 per cc. Now if the toxic products of saprophytes had been capable of destroying typhoid fever germs these should have gradually declined in number. The facts were, however, that one hour later the number present was 333 per cc.; 24 hours later, 63,198; and two days later the typhoid fever germs present were innumerable. This specimen was kept at blood heat. The germs were

carefully examined to make certain that they were true typhoid fever bacilli, and were found to be such. The culture was next placed in the ice chest and six days later the number of typhoid fever germs present had fallen to 888,000 per cc.; 12 days after seeding the number present was 832,100 per cc.; 20 days after seeding the number present was 375,000; and 36 days afterwards, 56,500. This experiment satisfied me that whether or not typhoid fever germs ultimately disappear in sewage they are not readily destroyed by the toxic products of saprophytes, but rather multiply and live long in their presence.

"More recently a similar experiment has been made by Dr. W. H. Horrocks, a well known English bacteriologist, in which Dr. Horrocks found abundant typhoid fever germs in sewage, filtered in the same way, after 42 days."

(Sedgwick, Vol. 8, p. 7972.)

SEWAGE FROM CHICAGO HAS AN INJURIOUS EFFECT ON ST. LOUIS.

Q. Professor, you have examined the tables introduced in evidence in this case, contained in the book known as Streams Examination?

A. I have.

Q. You have examined the tables and charts contained in the Illinois State Board of Health Report introduced in evidence by Professor Long?

A. I have.

Q. State whether or not you have examined the tables introduced in evidence by Professor Palmer aside from those made up by him and contained in Streams Examination?

328 A. Yes, sir; I have.

Q. Have you examined the tables and bacterial and chemical data of Professors Jourdan and Zeit upon the various chem-

ical and bacterial determinations of the water in the Illinois river and the sanitary canal not contained in Streams Examination?

A. I have; yes, sir.

Q. Taking into consideration, professor, all of the chemical and bacterial data introduced in evidence by the respondents, state whether or not the data so introduced leads you in any way to change your former opinion expressed in this case.

A. I have obtained from these tables and other data a much better knowledge of the process of chemical and bacterial purification going on at certain times and seasons in the Illinois river, but I have failed to discover any reason for changing the opinion which I expressed on my examination in chief a year ago, namely, that the principal part of the increase of typhoid fever in the city of St. Louis, since the first of January, 1900, has been due to the presence of deleterious elements contained in the public water supply, and derived from the unpurified sewage of the city of Chicago. The additional information which I have gained on the history of typhoid fever and other fevers in St. Louis, especially during the last year, has only served to strengthen that opinion."

(Sedgwick, Vol. 8, pp. 7972-3.)

CONDITIONS AS OBSERVED BY PROMINENT LOCAL PHYSICIANS, HOUSE FILTERS HAVE INCREASED IN USE AND PRACTICE OF BOILING THE WATER LARGELY ADVISED. YET TYPHOID DEATHS AND CASES INCREASED.

Since the use of the Widal test in St. Louis, about eight years ago, this favorable effect has been shown upon the typhoid death rate in St. Louis, for the reason that if the diag-

nosis test be made in the earlier stages of the disease, more intelligent treatment can be administered.

329 The result of this test has been such that a large number of physicians have been enabled to make a definite report as to the causation of death, and therefore a number of deaths have been attributed to other than typhoid, when, prior to the use of the Widal test, they would have been reported as produced by typhoid.

(See Dr. Goodman's testimony, Vol. 8, p. 7660; Dr. Fischel's testimony, Vol. 8, pp. 7612-14; Dr. Bremer's testimony, Vol. 8, p. 7626; Dr. Saunders' testimony, Vol. 8, p. 7859.)

According to the testimony of the local physicians, who are representatively the best in the city, typhoid fever, according to their observations, has increased in the city since the opening of the Drainage Canal.

(See Dr. Fischel's testimony, pp. 7806-12-14-16; Dr. Saunders' testimony, Vol. 8, p. 7859.)

It is a well known fact that the rise in typhoid fever during the latter part of 1899, prior to the opening of the Drainage Canal, was not due to defective water, but was confined to a certain locality in the city; in other words, it was localized, being confined to what is known as the West End, or the better class of people.

(See Dr. Saunders' testimony, Vol. 8, p. 7597; Dr. Bremer, Vol. 8, p. 7667; Dr. Taussig, Vol. 8, p. 7639; Dr. Goodman, Vol. 8, p. 7664.)

During the past few years the water in the private houses in St. Louis has been filtered to a great extent, and the practice of boiling water has been recommended by physicians, and has

been more generally adopted and followed than has been generally supposed. This practice has been followed by the people of the city of St. Louis, and yet the high typhoid death rate has continued to increase.

(See Dr. Bremer's testimony, Vol. 8, pp. 7663-4; Dr. Taussig's testimony, Vol. 8, p. 7640; Dr. Goodman's testimony, Vol. 8, p. 7662.)

330 The increase in typhoid fever deaths in St. Louis for the period 1900 to 1904, inclusive, over conditions existing for four years immediately prior thereto, was 77.7 per cent, based upon the number of deaths per 100,000 population in the city during the respective years, while the increase in total number of deaths, regardless of population, was 95 per cent.

(Lochridge's testimony, Vol. 8, p. 7936.)

The increase during the winter seasons of the respective periods was much greater than during the summer seasons. The evidence shows that for the period 1900 to 1904, inclusive, over the four years prior thereto, the increase during the winter months was 94.8 per cent for each 100,000 population in the city, while the total increase, regardless of population, amounts during the winter seasons to 118.2 per cent. The increase during the same season, based upon the 100,000 population table, was 65.7 per cent, and the increase regardless of population was 84 per cent.

(Lochridge's testimony, Vol. 8, pp. 7936 to 7940, inclusive.)

As heretofore stated, an attempt was made to discredit the typhoid mortality record of the city of St. Louis as introduced in evidence by complainant. It was charged that the great number of deaths reported by the local physicians as being caused by remittent, intermittent, typho-malaria, malaria, bilious, en-

teric, typho-pneumonia, congestive and simple continued fevers and published reports of the mortality records of the Health Department of the city were introduced for the respective years for the purpose of showing the reduction of the fevers mentioned. This was objected to for the reason that the reports themselves show that deaths due to other causes were included in the columns remittent, intermittent, etc., it being the contention of the defendants that a large portion of the deaths credited to the aforementioned diseases were, in reality, caused by typhoid fever, and that the total number of recorded deaths from typhoid had been increased on account of the reduc-
331 tion of the recorded figures for remittent, intermittent, etc.

No attempt was made by defendants to show that nothing save remittent, intermittent, etc., were recorded in the column specially set forth for that purpose, or that deaths probably due to these diseases were not embraced by the compiler of the reports in columns under deaths from other causes. In other words, the reports on their face show that no exact conclusions can be based upon them so far as intermittent, remittent, congestive and simple continued fevers, etc., are concerned. In view of this contention, Mr. Lochridge examined the mortality records of the city of St. Louis, including the various death reports made by the physicians of the city and the Health Department, wherein the cause of death was specifically set forth. These reports are copied by the mortuary clerk into large volumes for permanent record; these permanent records were also examined by Mr. Lochridge and from them an accurate compilation of deaths due to the various diseases in question was set forth by the year, the month, giving the age of the decedent, and the location of death, that is, as to where it occurred, in the residence or in one of the many hospitals of the city. This compilation made by Mr. Lochridge shows conclusively no sub-

stantial reduction in the reported deaths from malaria, typho-malaria and companion diseases in which the physicians are often times mistaken in their diagnosis, and should be properly classed as deaths due to typhoid fever.

(Lochridge's testimony, Vol. 7, pp. 7823 to 7928.)

From the tables prepared by Mr. Lochridge we reduce the following annual results:

	1896	1897	1898	1899	1900	1901	1902	1903
Remittent fever	40	29	26	15	15	23	17	17
Intermittent fever	12	12	16	25	10	12	9	11
Typho-malaria	50	42	30	31	36	23	34	36
Congestive fever	26	22	13	15	15	4	15	7
Continued fever	1	1	0	0	1	0	1	2
Malaria fever	27	34	23	35	40	28	38	53
Bilious fever	11	8	3	6	3	5	7	7

	1896	1897	1898	1899	1900	1901	1902	1903
Enteric fever	0	1	3	2	2	2	2	0
Totals	167	149	116	129	122	97	123	133
Deaths in which typhoid was a cause not included in other table	0	1	1	1	0	2	3	8
Typhoid pneumonia	13	18	17	14	9	18	15	26
Grand totals	180	168	134	144	131	117	141	167

The results as shown by the Lochridge tables are as follows:

Average deaths per annum for the period of four years prior to the opening, 106.5. Average per annum for the four years since the opening of the canal, 208, or an increase of 101.5 deaths per annum during the latter period as compared with the former period.

The average number of deaths reported as due to remittent fever, etc., being 156.5 per annum during the period 1896 to 1899, inclusive, and 140 per annum for the years 1900 to 1903, inclusive. Reducing the annual typhoid increase of 101.5 deaths by the apparent loss or decrease in remittent, etc., of 16.5 deaths, we attain on the basis of defendant's calculation an annual increase of 85 deaths from typhoid, or a percentage increase, upon the total mortality of the city from typhoid, of a fraction over 80 per cent annually. This increase of 85 deaths per annum represents one-fifteenth part of the increase cases per annum, or 1,275.

Valuing the life of the 85 deaths at $5,000, and the loss of labor and expense of treating and nursing the full 1,275 cases while sick for a period of 30 days each, we arrive at a proximate loss to the community and complainant from a financial point of view, as follows:

333 85 deaths at $5,000 each	$425,000
Care and treatment of 1,275 cases at $5.00 per day for 30 days	191,250
Loss of labor of 1,275 persons at $5.00 per day for 30 days	191,250
Total	$707,500

The total loss, financially speaking, is $707,500 per annum, or $2,830,000 for the full period of two years. In addition to this the suffering, distress and resultant injuries cannot, upon principles of humanity, be measured in dollars and cents.

334

ASSIGNMENT OF POINTS OF FACT AND LAW INVOLVED.

1.

A riparian population has the right to the use of a stream for drinking and other domestic uses in its natural state.

2.

Where discharges of sewage render the water of a stream impure or infectious, the injured have a right to ask and obtain relief through the power of the courts.

3.

Even though those residing upon the stream have the right to cast their waste into the stream so long as it does not substantially interfere with the convenience, health and comfort of the business interests of those residing on the river below, yet, such right does not extend to those residing upon another watershed so as to permit such discharges or deposits by artificial means into the stream draining a different watershed.

4.

When discharges have such effect as to render the conditions dangerous and unsanitary, the right to maintain such nuisance can not become permanent by prescription.

5.

The fact that others contribute to the injury constitutes no excuse or justification for the one charged to continue in the same.

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6.

The fact that riparian owners are allowed to discharge their waste and refuse into a stream so long as it does not create a substantial injury to those lower down, is merely a privilege even to the law of convenience and public policy. It is not a substantial vested right incapable of defeat.

7.

While the privilege of depositing waste into a river by riparian owners so long as no damage or substantial injury is experienced by those living lower down may be recognized on grounds of public policy and the general law of convenience and necessity of the people, it does not necessarily license others than riparian owners to discharge waste into the stream and that, too, regardless of whether it be a substantial interference with those below the point of discharge or not.

8.

Complainant has been materially and irreparably injured on account of the conduct of defendant in the operation of the artificial channel from Lake Michigan to the Des Plaines river, and the discharge of the raw sewage into the channel and thence into the Mississippi river, defendants having no right in law to convey the sewage of infectious material of two millions peo-

ple from a watershed above to people living upon another watershed.

9.

Germs of infectious diseases are shown to pass from Chicago to St. Louis and greatly injure the water of the Mississippi at St. Louis, and at all points on the Missouri shore below the mouth of the Illinois river.

10.

The waters of the Mississippi are shown to be more heavily burdened with disease organisms and infectious material
336 since the opening of the canal, January 17, 1900, than prior to that time, such increased infection being due to the discharge of the sewage at Chicago into the canal.

11.

The typhoid mortality at St. Louis, on account of defendants' action, has increased annually 77.7 per cent for the period of four years since the establishment of the nuisance as compared with the four years immediately prior thereto, such increase of typhoid mortality being due to said nuisance.

12.

Valuing each life to the extent of the annual increase of at least 80 deaths per annum for the four years at $5,000, and the loss of labor, cost of treating and nursing the additional or increased cases amounting to 1,200 (deaths multiplied by 15), occurring annually, calculated on the basis of $10 per day for loss of labor, medical treatment and nursing, it will be observed that the damage of complainant is of no trivial amount.

13.

From the standpoint of humanity and taking into consideration mental and physical suffering, permanent disabilities and all of the disagreeable elements entering into conditions and circumstances which produce death, and taking also into consideration the fact that no one community should attempt to relieve itself from sufferings of sickness and death at the expense of a neighboring community, the right and justice of this litigation instituted on behalf of complainant against defendant, is apparent.

14.

The injury inflicted upon complainant is actual, substantial, continuous, immediate and irreparable.

In the presentation of the case upon the demurrer to the court, a full line of authorities were submitted upon complainant's right to institute this proceeding, entitling it to judgment if the facts set forth in the petition be established, and
337 showing complainant's right to join both parties defendant in the action. The position assumed by complainant was upheld, both as to the jurisdictional question and its right to the relief sought. It, therefore, becomes unnecessary for us to again present authorities upon the foregoing propositions. We, therefore, shall confine the presentation of the case to the court by referring to the important facts established in evidence, together with the legal propositions arising therefrom.

The undisputed evidence shows that disease producing organisms or pathogenic bacteria are discharged from the sewers of a city into the drainage basin and when carried away by the

running stream remain in the stream throughout the life of the germ or organism, unless they be sooner introduced into some human system. In this way certain diseases are communicated from one individual to another. As the population of a city upon a watershed increases, the relative number of pathogenic bacteria discharged into the river upon which the city is situated increases, and thus the water of that river is being continually increased in contamination. Experience has shown that by an increase in the number of cases of a particular water-borne disease among persons residing upon a watershed, epidemic conditions are liable to be and often are produced upon the inhabitants of cities taking their water supply from the river in question at considerable distances below the point of infection. Of the water-borne diseases typhoid fever may be said to be the most aggravating. Germs of this disease are known to live for a considerable length of time in water and in sewerage, the length of time depending largely upon the special resistant force of each individual organism. Laboratory experiments have disclosed the life to range in the unsterilized waters of a polluted stream for a period of fifteen to thirty days. It is known to live in the mud and silt of the bed of a stream, being carried there by the process of sedimentation. It lives in moist soil for a number of months. So minute is this particular organism that it is practically impossible to discover it in waters of streams, although it is a known fact that such waters are very often typhoid infected. Sanitarians must, therefore, in passing judgment upon the sanitary condition of a water, take into consideration the longevity of the germ as disclosed by laboratory experiments, the length of time it is known to live in sedimentation basins and afterwards produce typhoid fever, and also take into consideration the urban population residing on the watershed above the point where the water

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is being used for domestic purposes; in fact, must consider all the physical facts and surroundings. If it be found that the time for the stream to flow from the point of infection to the water supply falls within the life time of the germ, the water in its natural condition must of necessity be condemned. There is a contrariety of opinion among the witnesses who testified in the case as to the exact longevity of the typhoid organism. There is no disagreement, however, upon the fact that they will live in the waters of the Drainage Canal, at least, six days. This is established by defendants' own witnesses, concurred in by complainant's witnesses, except that they refused to be bound by any fixed time or rule. Governed by the laboratory experiments which assimulate natural conditions in a living water as near as possible, it is safe to say that they will live in the waters of the rivers in question for a period extending beyond thirty days. That they pass from Chicago to St. Louis within the time flow of the water is in a sense an admitted fact, as shown by the statement of Professor Mason, one of defendants' witnesses, in which he said that there was necessarily a very large reduction in the number of pathogenic bacteria and typhoid organisms as they pass through the canal and down the river, yet undoubtedly some of the highley resistant organisms would survive the journey from Chicago to St. Louis.

Prior to the opening of the canal, the Chicago river had been in a state of putrification and decay. Septic action was continually taking place, the river remaining in this condition practically throughout the entire year. At times of floods and freshets, its contents were gulched into the lake, contaminating the waters of the lake with infectious disease producing organisms, resulting in increased typhoid deaths and cases in the city using Lake Michigan as its water supply. In order to alleviate this condition, the Drainage Canal was constructed, and

in doing so, defendants took into consideration only the safety and conveniences of the citizens of Chicago. No regard
339 was had to people living upon the Mississippi river watershed, save that sufficient water was introduced from Lake Michigan to partially destroy the noxious gases which formerly arose from the Chicago river caused by putricient conditions. The introduction of the 250,000 cubic feet of water from Lake Michigan, although seriously contaminated itself, has had a tendency to preserve the life and vitality of the disease producing organisms deposited in the Chicago river from the sewers of Chicago; as all of the witnesses agreed that dilution does not destroy, but rather preserves infectious material.

Not only is the sewage from Chicago conveyed rapidly from that city to St. Louis, but by the addition of the large volume of water from Lake Michigan, the sewage from LaSalle, Henry, Chillicothe, Peoria, Pekin, Beardstown and other points is carried more rapidly down the Illinois to the Mississippi than prior thereto. So that it may also be safely said that on account of the construction and operation of the canal, the contaminating material found in the Illinois river at its mouth is hastened from the above named points in such time as to preserve the life of a greater number than under conditions existing prior to January 17, 1900.

The population of the Illinois river watershed, based upon the number of square miles of area, exclusive of the city of Chicago, is far in excess of the population residing upon the watersheds of the Mississippi and Missouri rivers per square mile. Indeed, it is an undisputed fact that from the standpoint of population and drainage area, the Illinois river water, aside from the city of Chicago, is far inferior to the waters of the Mississippi or the Missouri. The Illinois river is the only means which nature has prepared for the carrying off of the filth and

sewerage of the population residing upon its watershed, and it is now burdened with more polluting and infectious material than is consistent with the requirements of an ordinary safe water supply. When the sewerage from the city of Chicago is added to it, the result, of course, becomes alarming and its passing into the Mississippi river at Grafton, thirty miles above St. Louis, renders the water of that river in an unwholesome and dangerous condition, as is shown by the increased typhoid mortality of the city of St. Louis.

RIGHT TO USE OF WATER IN ITS NATURAL STATE.

The inhabitants of a large and populous city have the right to use the water of the stream upon which the city is situated in its natural condition, free from infectious material deposited into it at points above. If the discharge of infectious sewerage and filth in the stream renders the waters dangerous and harmful to the people living below, such municipality or person creating the nuisance and causing the danger or damage may be enjoined from continuing the infectious discharges.

Am. & Eng. Enc. of Law, 2nd Ed., Vol. 30, 378.
Indianapolis Waterworks Co. vs. Strawboard Co., 57 Fed. Rep., 1000.
Trevett vs. Prison Association, 98 Va. 352.
Attorney-General vs. Birmingham, 4 Kay & J. 528.
Platt vs. Waterbury, 77 Am. St. Rep., 335.

In Platt vs. Waterbury, 77 Am. St. Rep., 335, the court decided that the use of a stream for drainage may, under some circumstances, be reasonable, although the water is thereby rendered unfit for its primary use, but the concentration of the filth accumulated by one proprietor, whether an individual or a

municipal corporation, and its discharge into the stream in such quantities that it is necessarily carried to the premises of another, where it produces a nuisance dangerous to his health and destructive of the value of his property, is unreasonable and creates liability. The right of a city to pour into a river surface drainage does not include the right to mix with that drainage filthy and noxious substances in such quantities that the river cannot dilute them nor safely carry them off without injury to the property of others. The latter act is, in effect, an appropriation of the bed of the river as an open sewer to carry such substances to the property of the lower proprietor and is an invasion of his property rights.

In Trevett vs. Prison Association, 98 Va. 332, the court
341 held that any use of a stream that materially fouls and adulterates the water, or the deposit or discharge therein of any filth or noxious substance that so far affects the water as to impair its value for the ordinary purposes of life; or anything which renders the water less wholesome than when in its ordinary state, or which renders it offensive to taste or smell, or which is naturally calculated to excite disgust in those using the water for the ordinary purposes of life, will constitute a nuisance enjoinable by a court of equity on behalf of the riparian owners residing upon the river below the point of the discharge of the polluting material.

Wood on Nuisances, 3rd Ed., Sec. 427, in this connection said:

"The right of a riparian owner to have the water of a stream come to him in its natural purity is as well recognized as the right to have it flow to his land in its usual flow and volume. But in reference to this, as with the air, it is not every interference with the water that imparts impurities thereto,

that is actionable, but only such as impart to the water such impurities as substantially impair its value for the ordinary purposes of life and render it measurably unfit for domestic purposes, or such as causes unwholesome or offensive vapors or odors to arise from the water and thus impairs the comfortable or beneficial enjoyment of property in its vicinity. * * * The pollution of water by artificial drainage which causes sewerage to flow into a stream, spring or well, whether done by a municipal corporation or an individual, constitutes a nuisance which entitles the owner to damages therefor, the rule being that a municipal corporation has no more right to injure the waters of a stream or the premises of an individual than a natural person."

Wood on Nuisances, Secs. 427-579.

CONTRIBUTION AND EXONERATION.

Where there are several contributing causes of the pollution and infection of a water course, one cannot escape liability for those living below and using the waters for domes-
342 tic purposes, because of such pollution by themselves.

Eliminating from the case the fact that Chicago is situated upon the natural watershed of Lake Michigan while complainant is situated upon the natural watershed of the Mississippi, and even though it be assumed that the same rights with reference to the disposal of its sewerage belong to Chicago as to any other city upon the natural watershed of the Illinois river, it cannot be claimed by the defendants that they have the right to pollute the waters of the Mississippi because there are other cities situated upon its watershed which contribute to the pollution after or before the water reaches the Mississippi at Grafton.

Crossley vs. Lightowler, L. R. 2 Ch. 478.
Tennessee Coal and Iron Co. vs. Hamilton, 100 Ala. 252.
Watson vs. New Milford, 77 American St. 345.
Am. and Eng. Enc. of Law, Vol. 30, 383.

In the case of Hill vs. Smith, 32 Cal. 177, a large number of persons were engaged in mining upon a small stream. It was held by proper proceeding that in as much as each contributed to the deterioration of the water so that the combined acts of all rendered it unfit for use, an action against one cannot be successfully defended on the ground that his act alone did not materially affect the water.

In Little Schuylkill Navingation Co. vs. Richard, 98 Am. Dec. 211, the evidence disclosed that a dam was filled by deposits of coal dirt from different mines on the stream above. Some of these mines were worked by defendants, others by persons entirely unconnected with them. It was held that, while the defendants could not be held liable for the entire injury done, provided the wrong could be supported by means of competent proof, yet the fact that others were contributing to the cause would not justify the perpetration of the act by defendants.

In Ferguson vs. Firmenich Manufacturing Co., 77 Ia. l. c. 579, the court, in this connection, said: "It is claimed by appellant that Linn Creek * * * has been used as a common
343 sewer by the city and inhabitants of the city of Marshalltown for many years, and was so used during the time in question; that in consequence of such use the water was polluted and rendered unfit for domestic purposes and for stock, and that defendant, at most, could only contribute to the results of which plaintiff complains. But, if that be true, it would not relieve

defendant from liability in this action. * * * If the claim of defendant be true, it could not escape responsibility for the wrong because others contributed to it."

In the case of Tennessee Coal and Iron Co. vs. Hamilton, 100 Ala. 252, the court held, that, while the proper riparian owner may use the waters of a stream and to a certain extent impair its purity, he cannot, however, so pollute it as to render it unfit for the domestic use of lower riparian owners, and in an action instituted by the lower riparian owner for the pollution of the water above, the plea that plaintiff was guilty of negligence contributing to the injury, in that failure was had to take due precautions to prevent it, is insufficient.

In Watson vs. New Milford, 77 American St. Rep. 345, the Court held that a municipal corporation is liable to a lower riparian proprietor for a nuisance created by the discharge of the sewerage of the city into the stream, and although some riparian owner may have previously fouled the stream to the injury of those below him, it does not constitute a license for others to commit similar acts.

The fact that Peoria, Pekin, Havana, LaSalle, Beardstown and Joliet sewer into the Illinois river does not constitute the right of defendants to likewise discharge the sewerage from the city of Chicago into the Illinois river.

Noland vs. New Britain, 69 Conn. 668.
Wheeler vs. Fisher Oil Co., 9 Ohio Dec. 294.
Jackman vs. Arlington Mills, 137 Mass. 277.

In Morgan vs. Danbury, 67 Conn. 484, the plaintiff, a riparian mill proprietor, alleged that defendant, without making compensation or attempting to acquire any rights in the

344 premises, is discharging and threatening to discharge in still greater quantities, waste matter, sewerage and other noxious, corrupt and impure substances from its sewers into the stream so as to pollute it and seriously damage his land and mill privilege; that such discharge poisoned and corrupted the air of the neighborhood and endangered the health of the plaintiff, his workmen and others, and had already partly filled his dam with filth and prevented him from disposing of his land for building purposes. He prayed for an injunction against the continuance of the nuisance, and to restrain the pollution of the water of the stream. The trial court found these allegations to be true, that the plaintiff's injuries could not be adequately compensated in damages, and that the acts complained of constituted a public nuisance, and granted the injunction.

It was held by the appellate court that if the stream was in such condition that the defendant's discharge of the sewerage worked a nuisance, it had no right to use the stream for that purpose, and that the fact that others were contributing to the pollution constituted no defense in the hands of the defendant.

Fahnestock vs. Feldner, 56 Atlantic, 785.

THE RIGHT TO CONTINUE A PUBLIC NUISANCE CANNOT BE ACQUIRED BY PRESCRIPTION.

The fact that Illinois and Michigan Canal was constructed many years ago for the purpose of aiding navigation, and since 1871 has been used for the purpose of partially carrying off the discharges from the stock yards in the southern part of the city of Chicago, and the fact that this canal enters the Illinois river at Peru, does not constitute a right by prescription upon the part of defendants to construct the main drainage canal in

question, and operate it in the manner as charged in the bill. Aside from the legal proposition involved, it affords defendants no relief whatever. It may be said that the Illinois and Michigan Canal has never carried from the south fork of the south branch of the Chicago river more than 10,000 cubic feet of
345 water or sewerage per minute. It has had no marked effect upon the conditions in the Chicago river. After being conveyed into the canal, it required considerable time to pass to Peru on account of its almost imperceptible current. During this period septic action took place and what few pathogenic bacteria remained in it were destroyed. After the Illinois was reached it again met a slow and sluggish current, which, during a greater part of the year, was in a state of quiescence caused by the various dams across the river. No such conditions have existed since January 17, 1900, the date of the opening of the main drainage channel. Since the above date the entire sewerage from a city with a population of two million people has been thrown into the river at Joliet, and by the addition of from 250,000 to 300,000 cubic feet of water per minute has been forced rapidly onward to the mouth of the Illinois river within such time as was absolutely impossible to bring about the death of the disease producing organisms. The construction of the artificial channel and the discharge of Lake Michigan through it has changed conditions entirely in comparison with those which existed prior thereto. So that the fact that a certain portion of the sewerage of Chicago was discharged through the Illinois and Michigan canal prior to January, 1900, does not bestow upon defendants the right either to continue therein or to construct a larger channel capable of producing, and which does produce, irreparable injury to complainant.

In discussing the question as to whether or not the right to maintain a public nuisance can be acquired by prescription, the Court, in the case of Wright & Rice vs. Moore, 38 Ala. l. c. 598, said: "In dismissing the subject, we deemed it proper to remark that there can be no prescription for a public nuisance, and that no length of enjoyment would legalize the continuance of a mill pond destructive of the health of the surrounding community."

In Goldsmid vs. Commissioners, 1 Law Rep. 167, the court said: "It is to be observed also, which is an observation of importance in this case, that the injury to plaintiff is not con-
346 fined to his lake, to which so many of the witnesses for defendant direct their testimony, but in fact extends to the whole of his land. But it is important to observe what the position of a gentleman in the situation of plaintiff is. If he comes to the court and complains very early, then the evidence is that it is not perceptible—it is wholly inappreciable—and you get evidence after evidence for the defendants (the pollution being slight and perhaps only observable at some times and on some occasions) saying, 'You have no proof at all that there is any appreciable pollution, and you must wait until it becomes a nuisance.' Then he waits for five or six years until it is obvious to everybody's sense that the pollution is considerable, and then they say, 'You have come too late, you have allowed this to go on for twenty years, and we have acquired an easement over your property and the right of pouring the sewerage into it.' My opinion is that any person who has a water course flowing through his land and sewerage which is perceptible is brought into that water course, has a right to stop it; and that when the pollution is increasing and gradually increasing, from time to time, by the additional quantity of sewerage poured into it,

the persons who allow the polluted matter to flow into the stream are not at liberty to claim any right or prescription against him. * * * My firm conviction is that in this, as in all great dispensations and operations of nature, the interests of individuals are not only compatible with, but identical with the interests of the public; and although in this case I have only to consider the injury to a private individual, I believe that the injury to the public may be extremely great by polluting a stream which flows for a considerable distance, the water of which cattle have been in the habit of drinking, the exhalations from which persons residing on the banks must necessarily inhale, and this at a time when the attention of the public and the court is necessarily called to the fact that the most scientific men who have examined the subject are unable to say whether great diseases among cattle and contagious diseases affecting human beings, such as cholera or typhus and the like, may not in a great measure be communicated or aggravated by the absorption of particles of feculent matter into the system which are either
347 inappreciable or scarcely appreciable by the most minute chemical analysis. It is impossible in that state of things to say what amount of injury may be done by pollluting even partially a stream which flows a considerable distance."

In the case of Mills vs. Hall, 9 Wend. l. c. 416, the Court said: "There is no such thing as a prescriptive right, or any other right, to maintain a public nuisance. Admitting that defendant's dams had been located and maintained for more than twenty years, and that during the whole of that period it has rendered the adjacent territory unhealthy, such length of time can be no defense to a proceeding on the part of the public to abate it, or to an action by any individual for the special and peculiar injury which he may have suffered from it."

In Attorney-General vs. Copper Co., 152 Mass. l. c. 452, the Court said: "We have not overlooked the cases in which it is said that no length of time will legalize a nuisance. The reason of the rule to which these cases refer is, that criminality can gain no toleration in the law. The creation and maintenance of a public nuisance is punishable criminally; hence the element of criminality, which characterizes the act of creating it should prevent the acquisition of a right to maintain it."

Commonwealth vs. Upton, 6 Gray, 473.
Morton vs. Moore, 15 Gray, 573.
New Salem vs. Eagle Mill, 138 Mass. 8.

In State vs. Rankin, 3 South Carolina, 448, the Court said: "The right to property from long possession, either directly from the operation of the Statute of Limitations, or arising from the presumption of an original cession by grant, cannot be applied to sanction or uphold its use or devotion to purposes not permitted by the State, either as affecting its own sovereignty or the rights of third persons. Chitty, in his 1st volume of Criminal Law, 160, says: 'It has been repeatedly held that no length of time can legalize a public nuisance, although it may afford an answer to an action by a private individual;' and
348 Chief Justice Parsons in Town of Sloughton vs. Baker, 4 Mass. 522, observes 'that no laches can be imputed to the government, and against it no time runs so as to bar its rights.' While the long possession may confer a right to the land flowed, and all the proprietory incidents which follow the title to property, it cannot be set up as a bar to the abatement of a nuisance on behalf of the public. A right to violate the law is not to be presumed as allowed by the State itself, for this would be inconsistent with the very purpose for which it was created, and would

involve an absurdity too violent to be entertained even for a moment."

NO ONE HAS THE RIGHT TO INCREASE THE VOLUME OR HASTEN THE FLOW OF A STREAM AGAINST THE WISH AND WILL OF LOWER RIPARIAN OWNERS, AND ESPECIALLY IS THIS TRUE WHEN DAMAGE OR INJURY EITHER RESULTS OR IS LIKELY TO RESULT.

Although water may be permitted to run along its natural course and the flow in its natural course may be to some extent hastened, there is, however, no right in law to hasten the flow or impose an additional volume by entering upon the servient estate using artificial channel for drainage purposes, thereby increasing the drainage area and thereby burdening the drainage facilities.

Farnham on Water and Water Rights, Vol. 2, 1052.
Ward vs. Peck, 49 N. J., 4992.

Such an act is a trespass which may be resisted by the injured party, and for that purpose, all the machinery of law is at his service.

Farnham on Water and Water Rights, p. 487.

In passing upon the rights of a riparian owner, it may be said as a general proposition that such owners are entitled to the usual and natural flow of water in the stream without
349 material alteration; that is, without the artificial increase or reduction in volume and velocity of current. In the case of the East Jersey Water Company vs. Bigelow, 60 N. J., p. 207, the court said: "It is the right of every owner of land upon a stream to have the water come to him in its natural flow undimin-

ished in quantity and unimparied in quality, and it may be added, with no increase in the volume except from natural causes. Therefore it is an actionable nuisance, at common law, for a mill owner or other person to turn a new stream into the stream, or by means of a reservoir to increase the volume of water naturally flowing into the stream and it is no defense for an action for such an injury that the person complaining is benefited by the increase of the volume of water, for no person can be compelled to have his premises improved and has a right to their enjoyment in their natural condition according to his own tastes and inclination."

Wood on Nuisances, pp. 499 and 500.

In Merritt vs. Packer, First Coxey, 496 to 533, Chief Justice Kinsey said: "It would be equally unreasonable that any man should have the right to turn more water over the land of his neighbor than would naturally come in that direction, and so far as regards the right, it is altogether immaterial whether it be productive of injury or benefit. No one has the right to compel another to have his property improved in any particular manner. It is as illegal for him to receive the benefit as to submit to the injury."

Tillotson vs. Smith, 32 N. H., 490.
Gerrish vs. New Market Manufacturing Company, 30 N. H., 478.

In Plattsworth Company vs. Smith, 57 Neb. 579, it is held that riparian owners are entitled to the right of usual water flow in a water stream without material alteration.

In Tillotson vs. Smith 32 N. H., 490, the court, speaking through Judge Bell, said: "Every owner of land situate
350 upon a stream has a right to the natural flow of the stream;

a right to insist that the stream shall continue to run uti current solebat; that it shall flow upon his land in its usual quantity at its natural place and at its usual height, and that it shall flow off his land upon the land of his neighbor below in its accustomed place and at its usual level. This right has been as an incident to the water of his land and he can not be deprived of it by grant, actual or presumptive. Whenever, by reason of the interference of the owner above, the water is diverted from his land and made to run elsewhere, or the water of other streams naturally running elsewhere, is turned upon his land, or the water of the natural stream is made to flow upon his land at a different place from its natural channel, or at a different level, or in an unnatural manner, and so, whenever, by the acts of the owner of the land below, the water is obstructed, or drawn down or made to run off in an unusual place or in an unusual manner, and actual injury ensues to any material amount, the owner of the land may maintain an action for such injury. In short, if any person, above or below, shall make any change in the natural flow of the stream, to the material injury of the owner situate upon it, or by any interference shall prevent the stream from flowing as it was wont to flow, to such injury, he is liable for the damage he may occasion. These rights are subject to the rights of the owners of the land situate above and below upon the stream to make a reasonable use of the water upon their own land while it is passing along the same.

The precise case before us, which is of a class of which the instances are comparatively unfrequent, that of turning a stream from its natural channel and forcing it to run in the channel of another stream, was decided in Merrill vs. Parker, Coxe, 460, cited in Agnell on Watercourses, 335. The point as it arises in the French law is fully discussed in Pardessus and Servitudes, Secs. 82, 85, 88. It seems very evident that if a man's land is

materially damaged by water thrown upon it by reason of the acts of another, it can make no difference what the source of the water may be; whether it be backwater, or the flowage of the same, or the water of another stream. The wrong consists in
351 turning any water upon the land which does not naturally flow in that place, and it can make no difference if the water wrongfully turned upon a man's land against his will flows in the channel of an ancient stream, or in a course where no water flowed before, if similar damage results: Howell vs. McCoy, 3 Rawle, Huston, J.; Bealey vs. Shaw, 6 East, 213, Ellenborough, C. J.; Mason vs. Hill, 3 Barn. & Adol., 304, Tenterden, C. J.; King vs. Tiffany, 9 Conn., 162; 3 Kent's Com., 439.

It is a long established principal of the common law that wherever any act injures another's right, and would be evidence in future in favor of the wrong-doer, an action may be maintained for an invasion of the right without proof of any specific injury: Mellor vs. Spateman, 1 Wms. Saund., 346, note 2. This principal has been recognized here in the case of Woodman vs. Tuffs, 9 N. H., 91; Snow vs. Cowles, 22 Id., 302; Cowles vs. Kidder, 24 Id. 379; Bassett vs. Salisbury Mfg. Co., 28 Id. 455. In the last case it was held that the state of the plaintiff's interest might be properly inquired into, because, if he sustained no damage in fact, and had no interest that could be affected by the danger of an accruing easement, he might not recover any damages. That is not the present case. The plaintiff appears to be owner in fee."

In connection with the foregoing, we call the Court's attention to the following:

Evans vs. Merriweather, 38 A. Dec., 106.
TenEyck vs. Delaware Canal Co., 32 A. Dec., 232.
Miller vs. Miller, 39 A. Dec., 544.

Norton vs. Valentine, 39 A. Dec., 220.
Elliott vs. Fitzbury, 57 A. Dec., 85.
Newhall vs. Iresom, 54 A. Dec., 794.

Applying the doctrine of the foregoing cases to the facts here involved, we submit that complainant has the right to the use of the Mississippi river in its natural and accustomed flow; that defendants have no right to change or alter the velocity of the stream or the volume of water passing down it. By the increased volume of water discharged into the Illinois river
352 not only is the height of the water increased, but also the velocity likewise becomes much greater, the particular damage resulting to complainant in this respect being that in as much as the velocity of the current and the volume of water is increased, the longevity of disease producing organisms is greatly advanced and the rapidity with which they pass from Chicago to St. Louis is largely accelerated. As shown by all of the evidence in the case, this constitutes a material and substantial, in fact, a great damage and injury to complainant. There being no contrariety of opinion that by the increase in the volume of water the life of the disease producing organisms is greatly increased, and likewise, by the increase of the current, the distance traveled by pathogenic bacteria within their life time is largely extended.

The above and foregoing facts constitute really the basis of the damage and injury complained of. It is a matter of no consequence as to the manner in which damage results from those living below on account of the increased volume or velocity of the stream. The application of the principle of law in question is the same, whether it comes in the way of destruction of property, or whether by overflowing the land or the carrying away of dams and docks, or whether it come by carrying large quantities of infectious matter which, when taken into the human system, when the water is used for domestic purposes and creates

disease. In fact, if there be a consequential difference, it would be more important for the courts to protect lower riparian owners from an increase in the volume and velocity of the streams on account of the quickening of the passage of infectious material and of the increased quantity of such infection that may be thrust upon the population at a given point below.

When we consider the fact that no scientific observer has yet been able to formulate a table showing the exact longevity of disease producing organisms deposited into running streams and when we take into consideration the fact that the longevity of such germs depend largely upon physical surroundings and atmospheric conditions, together with the admitted fact that such germs exist in water for a considerable length of time, there is no way to avoid the conclusion that the greatest of care and precaution should be exercised by those having in charge
353 the duty of determining whether or not a given water is the cause of the unwholesome conditions of a city using the water of the river for domestic purposes, especially is this true when the fact also stands admitted that large quantities of sewage from a community populated with two millions of people is discharged into the river at a point above the city in question.

Defendants, by means of the artificial channel which has been constructed from Chicago river to the Des Plaines river, deposit large quantities of infectious material in the water, starting it on its way from the source of infection, subjecting all persons residing upon the river below that point to its damaging results. There is no testimony from a practical sanitary standpoint that enables one to draw the conclusion that at all times and seasons of the year under the various changing conditions of the river that it has become freed from its pathogenic bacteria before the Mississippi river is reached at Grafton. This

condition is emphasized when it is known that the velocity of the river varies considerably. Even though it be admitted that during exceedingly low stages of the river more time is required for the flow to reach the Mississippi, that the polluting material becomes largely concentrated, a large portion of such infection or pollution may disappear within a given time, and that, too, before the mouth of the river is reached, but such conclusions can not be made applicable to conditions when the river is at flood, or during the winter seasons when saprophytic action is limited and septic conditions practically removed from the water. Nor will it be sufficient to destroy the more persistent and highly vitalized pathogenic bacteria.

The evidence shows that a number, in fact all, of the typhoid epidemics of consequence, have been produced by infectious water. The epidemic at Washington in 1898, caused by a typhoid epidemic at Cumberland, Maryland, 175 miles up the stream; the epidemic at Detroit, caused by typhoid germs being deposited in the St. Clair river at the mouth of Black river, a distance of 67 miles from Detroit, and where the water was required to pass through St. Clair river and Lake St. Clair before it
354 reached the intakes of the Detroit waterworks; the epidemic at Lawrence and Newport, where the water was inducted into large reservoirs and so remained for a period of from two to three weeks, and yet preserved sufficient of the typhoid bacteria, alive and virulent, to produce the disease. The epidemic at Pittsburg, Penn., caused by typhoidal conditions at Oil City, 113 miles above. In addition to what may be said with reference to the epidemics, it may also be said that the unusual high typhoid death rates occurring in various localities throughout the country have been attributed to infected water supplies. Cincinnati, Ohio, with a high typhoid mortality, receives its water supply from the Ohio river, and is known to be infected

from the sewers of Pittsburg, a distance of more than 200 miles away; Buffalo, which obtains its water supply practically from the mouth of Lake Erie, suffers with a high typhoid mortality, caused by the sewage discharge into the Lake at Cleveland and other points. Covington, Kentucky, and New Albany, Ind., suffer severely from the disease. At these points the water is pumped into large reservoirs, where it is confined for more then 30 days, during which time it retains sufficient germs of the disease that when distributed to the consumer, typhoid conditions result. The City of Chicago, one of the greatest typhoid-ridden cities in the United States, takes its water supply from Lake Michigan, heretofore looked upon as an acceptable source for pure water. The experience of the city, however, has demonstrated that the sewage from Chicago itself has so contaminated and infected the water of the Lake at such distance from the shore so as to render it questionable whether the intakes could be extended a sufficient distance into the Lake to be free from infectious material. (See Rudolph Herring's testimony, Vol. 8, pp. 740 to 742, inclusive.)

In his testimony in Vol. 8, page 719, Dr. Barker, one of defendant's witnesses, testified that the city of Toronto suffered with typhoid due from the infectious condition of the water of Lake Ontario, that the intakes were situated about three miles out from the shore, and that, in order to be secure from the contaminating effects of the sewage of the city, it would be necessary to extend those intakes a distance of 100 miles. This, of course, would reach far across into the state of New York,
355 but demonstrates the fact that even the large lakes of the country may become subject to infectious material even to their very centers.

Prof. Mason, at page 6960 and 6961 of the printed record, stated in his opinion that in consideration of the facts regarding

the Chicago sewage being dumped into the Illinois river as at present, and the facts concerning the infection of the Illinois river with the germs of typhoid fever coming from the sewers of that city, such germs would be largely destroyed by the time the mouth of the Illinois is reached, although some resistant organisms would pass beyond that point, some typhoid germs having greater vitality than others, resembling largely a crop of turnips grown upon good soil as compared to a crop grown upon poor soil; that all things considered, it is impossible to tell what is the longevity of specially resistant cells, experimental data having shown that for the general mass the longevity is fairly well fixed, but that with reference to a great many, and especially the highly resistant individuals, we are still in total ignorance.

Dr. E. G. Smith, also one of defendants' witnesses, testified that the population residing upon the watershed of the particular stream in question is of great importance, and that as the population increases, the sanitary condition of the water will naturally become inferior. Dr. Smith also stated that the water in a running stream is continually changing from day to day and likewise the saprophytic influences change. Oxidation, sedimentation, dilution, in fact, all of the factors which enter into the destruction or preservation of pathogenic bacteria, do not remain the same for any considerable length of time. Recognizing the infectious conditions of a running stream due to typhoid bacilli, Dr. Smith, as consulting sanitary engineer for the waterworks situated at Beaver Falls, in 1903, after hearing of the typhoid epidemic at Butler, Pennsylvania, a town situated 72 miles above, wrote to the waterworks company of that place warning them against permitting the raw water to be taken into the reservoirs without filtration and to be exceedingly careful in the operation of the filtration plant else

356 typhoid conditions would become prevalent in the latter city, rendering the company liable for damages on account of inferior water supplied.

(E. G. Smith's testimony, Vol. 7, pp. 6828 to 6846.)

Profs. Long and Palmer, who conducted a series of chemical analysis of the waters of the respective rivers and Lake Michigan, stated in their cross-examination that pathogenic bacteria could not be observed from a chemical standpoint or by means of chemical analysis; that there was a certain nitrogenous residue exposed in the analysis, which, of course, contained the living organisms, if there be any, but as to the character of such living organisms, no determination could be made.

(See Long's testimony, Vol. 5, p. 3496, and Palmer's Vol. 5, page 3462 to 3467, inclusive.)

Prof. Jordan, at page 6344 to 6345 stated that in his opinion "the most convincing evidence of the presence of typhoid bacilli in a given water during a given period would be the tracing of typhoid to that water, it being assumed that other sources of infection were sufficiently well examined to permit the establishment of the conviction that the particular water under consideration at the particular time stated, was responsible for the production of the cause of typhoid fever;" and, that "the best evidence as to water being typhoid infected is the result which it produces upon a community using it for domestic and drinking purposes," that there is no royal road to the accomplishment of determining the existence of pathogenic bacteria in water.

We, therefore, submit to the court that, in view of all the unquestionable facts and circumstances presented by complainant, together with the fact that defendant discharged disease germs into the canal, coupled with the fact that there has been

of St. Louis, it is apparent that pathogenic bacteria do pass from an increase of 77.7 per cent of the typhoid mortality in the city Chicago to the Mississippi river at Grafton and seriously
357 affect the sanitary condition of complainant's water supply.

One of the most remarkable disclosures in this investigation is found by the discovery of the bacilli of anthrax and tentinus in the waters of the Illinois river. This discovery was made by Prof. Zeit in his bacteriological observations of the water since the opening of the drainage canal.

Not only has the act of defendants been damaging to the people of the city of St. Louis, which constitutes one-third of the population of complainant, but also renders unsuitable the water supply of the people residing upon the Mississippi river from a point opposite Grafton to the Southern boundary line of the State.

Prior to the opening of the drainage canal, the city of St. Louis was furnished with a water supply equally as good as that obtained by a majority of the great cities of the country, its typhoid mortality being as low as that of Boston and lower than that of Chicago, Philadelphia, Buffalo, Cleveland, Baltimore and Cincinnati. Since that date, it has lost its former position and now assumes rank in the second class of cities, furnishing the greatest number of typhoid fever deaths per one hundred thousand population.

This increase of typhoid in St. Louis has gradually grown while physicians have advised the use of private filters and boiling of water. This advice has, to a large extent, been followed, and the practice of following it has gradually increased. The natural effect looked for would be a reduction in the number of typhoid cases; we, however, have an opposite result.

Considering the loss of life, the mental and physical suffering, along with the cost which typhoid conditions bring to a community as well as the harm done to the commercial interests of the State, we can appreciate only partially the injury inflicted upon complainant by the careless manner in which the sewage of Chicago is deposited into the Illinois river. It is not only encumbent upon the public to look well after the health of the people in every regard, but also important that water supplies receive careful and proper attention. Typhoid fever
358 is termed by scientists as a disease of civilization. "For every death from it, someone is criminally liable." While it is true, it may be impossible to eradicate it, but sufficient has been learned in recent years to know that it can be largely reduced and avoided.

Applying this obligation on the part of the public, to the facts as herein shown to exist, and the points of law heretofore enunciated, we submit that complainant has the right to ask the interference of the court to compel the State of Illinois and the Sanitary District of Chicago to forego the discharge of the sewage of the city of Chicago into the Illinois river. No objection is here made to the construction of the canal or of the transmission of water from Lake Michigan through it. It is, however, insisted that in as much as defendants disregarded their plain duty by failing to put its sewage through a course of treatment, removing from it the infectious material, before being discharged into the canal, they should now, either, be required to subject it to such treatment or discontinue its discharge into the river.

While we have thus spoken of conditions that exist at the present time, and have existed since the opening of the drainage canal, January 17, 1900, we have not referred specifically to conditions which will unquestionably occur in the near future, un-

less some remedy be afforded complainant. The Illinois river is now burdened to its limit in caring for the waste, filth and sewage deposited in it by the people residing upon its natural watershed. The population upon the Mississippi and Missouri rivers will naturally grow; and will grow rapidly. The city of Chicago, judging its future by the past, will not remain as it is. The time is not far distant when we may expect a population of five millions of people in that municipality. It is therefore natural to believe that ere long the waters of the Mississippi river below Grafton will become more contaminated with infectious material so as to increase the typhoid mortality of all cities taking from it their water supply. Complainant, therefore, asserts its right to preserve its waters in their natural condition as near as may be consistent with the convenience
359 and good of its own people. It, therefore, asks that its prayer as set forth in its bill heretofore filed, be granted.

Respectfully submitted,

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